AN EXPERIMENTAL INVESTIGATION OF RADIOSONDES

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by

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ABSTRACT

Radiosonde information is extensively used in the analysis and forecast of meteorological phenomena and the accuracy of both analyses and forecasts is dependent primarily upon the accuracy of the meteorological parameters determined from radiosonde flights. To evaluate the accuracy obtainable, 50 radiosonde flights were launched from the U. S. Naval Postgraduate School, Monterey, California. Thirty-five flights carried aloft the AN/AMT-4B model transmitter alongside the prototype AN/AMT-11DX transmitter and 15 flights carried the AN/AMT-11C model along with the AN/AMT-4B. All data obtained were reduced by the Geophysics Division, Pacific Missile Range, Point Mugu, California, on a CDC-3100 computer and graphically by the experimenter on the WBAN-31 series adiabatic charts. Values of temperature, relative humidity, and pressure as determined by each instrument were compared at each 3-minute interval of each flight and values of temperature, pressure-altitude, relative humidity and dewpoint were compared at standard pressure levels. The results obtained afforded a realistic evaluation of the various sensing elements under field conditions and indicate an urgent requirement for the development of a more accurate water vapor sensing device and replacement of the radiosonde baroswitching circuit by a hypsometer for precise determination of pressure values.

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1. Introduction.

Radiosonde information is extensively used in the analysis and forecast of meteorological phenomena and the accuracy of both the analyses and the forecasts is dependent primarily upon the accuracy of the meteorological parameters determined from the telemetry of information from the radiosonde instruments in flight. Under the auspices of the Naval Air Systems Command Division of the Department of the Navy, 50 radiosonde flights were launched from the U. S. Naval Postgraduate School, Monterey, California, with each flight consisting of two radiosonde transmitters; one telemetering temperature, relative humidity and pressure information at a frequency of 1680 megacycles and the other transmitting the same information at a frequency of 403 megacycles. The AN/AMT-4B transmitter was used for all flights and the prototype transistorized AN/AMT-11DX and AN/AMT-11C model transmitter were launched on 35 and 15 of the flights, respectively.

The AN/AMT-4B transmits an amplitude-modulated signal at a nominal frequency of 1680 megacycles. The 1680-mc transmitted signal provides telemetry of meteorological data and serves as the direction-finding or tracking signal for the Rawin Receiver (R-301B/GMD-1). The AN/AMT-11DX and AN/AMT-11C both transmit a pulse modulated signal at a nominal frequency of 403 mc. The AN/AMT-11DX transmitter is a hybrid type consisting of a vacuum tube (RF oscillator) and three transistors; the AMT-4B and AMT-11C transmitter use vacuum tubes only.

An equipment configuration as shown in Figure 1 was used for all flights and the procedures set forth in the Manual of Radiosonde Observations[3] for ground-handling of equipment and evaluation of data were

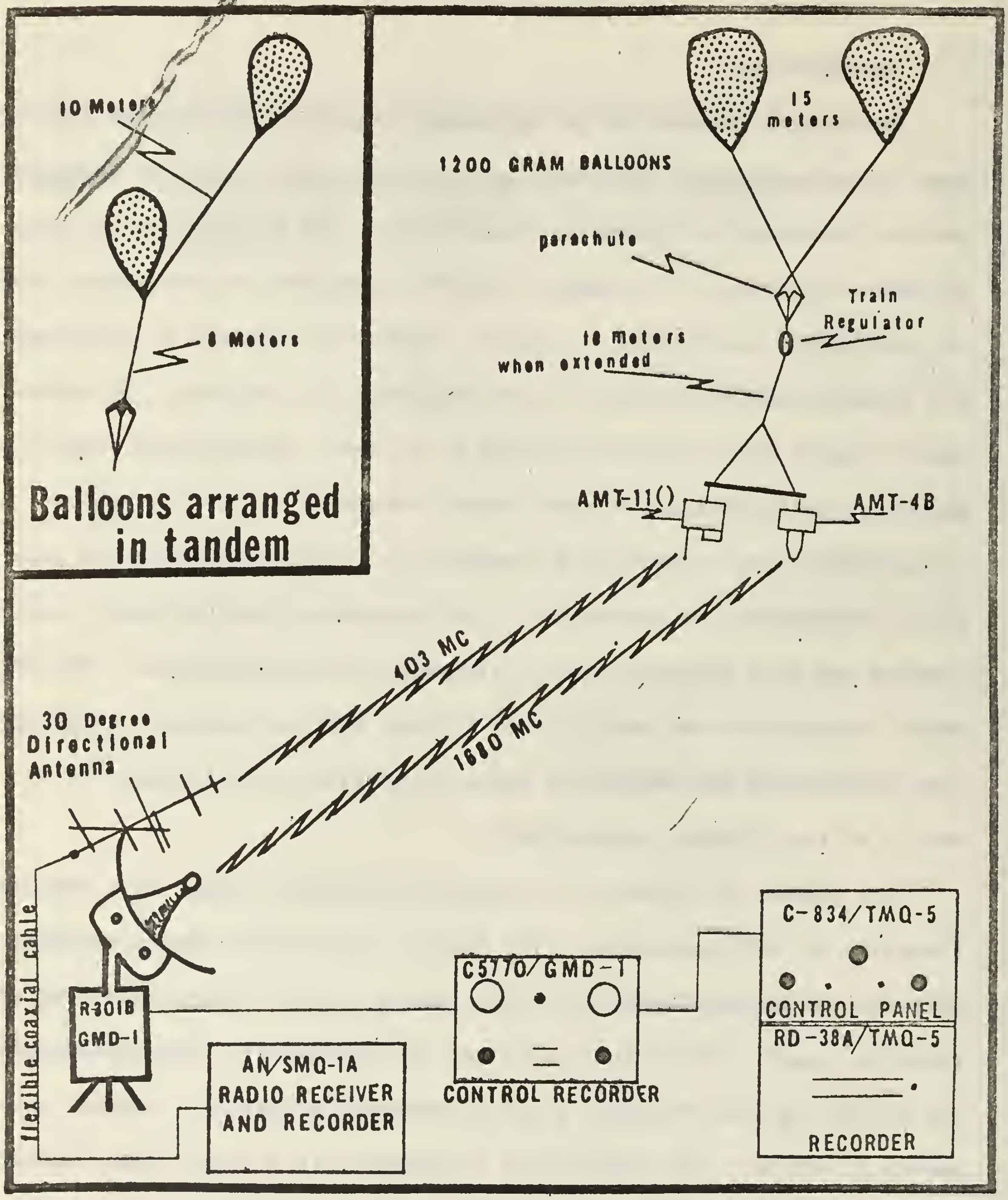


Figure 1. Ground and Flight Equipment Configuration. Inset shows tandem ballon arrangement used in flights seven, eight, and nine.

followed throughout most of the conducted research. Departures from prescribed procedures are noted with comments as appropriate.

The data obtained from all of the soundings were reduced by the Geophysics Division, Pacific Missile Range, Point Mugu, California, and graphically by the experimenter and Postgraduate School Aerographers on the WBAN-31 series Adiabatic Charts. Initial plans called for a determination and evaluation of the differences in observed temperature and relative humidity values along with the induced differences in pressure-altitude values at standard isobaric levels. However, it was discovered during the data collection that the pressure indicated by the two instruments at any one time usually did not agree; hence, the temperature and relative humidity at a particular pressure level could agree only by chance. In order to get a true comparison between the two instruments it became necessary to determine relative humidity, temperature and pressure differences as a function of the common parameter of time. The results of the latter differences are described in detail in Section 7 and the differences in the various parameters at standard pressure levels are elucidated upon in Section 6.

As a further aspect of this study, a comparison between the values of pressure-altitude determined by numerical reduction of the data with the graphical values obtained from the same respective flight record was performed and is presented in Section 13. A comparison between the temperature and relative humidity values is not included because the program which reduces the SMQ-1 (AN/AMT-11)[1] data requires values of

[1]Omission of the AN/AMT-11 model designator implies that the statement(s) applies to both types used in the experiments.

temperature and relative humidity in its input format, and the program which reduces the GMD-1 (AN/AMT-4B) data solves numerically the equations of the CP-223( )/UM Humidity-Temperature Computer and uses the resulting values to compute pressure-altitude (along with dew point, mixing ratio, refractive index, speed of sound, density and wind velocity). A qualitative comparison of the temperature and relative humidity values determined by the CDC-3100 computer with those corresponding values determined visually on the hand calculator revealed such minute discrepancies as to rule out the feasibility of a detailed study of the differences. This area of study was conducted to justify the proposal that radiosonde observation stations transmit raw data to centrally-located computer facilities for reduction and coded transmission, thereby decreasing the manhour requirements for data preparation and the time lapse between radiosonde launch and transmission of the coded message.

2. General Comparison of Instruments.

All transmitters tested employ a ceramic-resistor type temperature element with a negative temperature coefficient of resistance; i.e., the resistance decreases as the temperature increases. Accuracy of temperature measurement depends on the ratio of the element's resistance at one temperature to that at another temperature, and does not depend on absolute resistance at any one temperature. The elements have a white exterior in order to minimize the effect of solar radiation during daytime flights.

The relative humidity element on the AMT-11DX and AMT-11C is an electrolytic-type resistor consisting of a lithium-chloride coated plastic strip with metallic edges which serve as electrodes. Its resistance varies with humidity and to a lesser extent with temperature, increasing as the temperature and relative humidity decrease. A condition of oscillator instability is created by the high element resistance at extremely low values of temperature and humidity and this condition is overcome by placing a 1.2 megohm resistor in parallel with the element. This resistor produces an audio frequency of about ten cycles per second during periods of very low humidity and the signal has come to be known as "motor boating".

The humidity element of the AMT-4B is a carbon-coated plastic strip with electrode edges and its resistance decreases as the relative humidity and the temperature decrease, At low humidity values and higher temperatures (say 20%, and 20C) the coefficient of resistance of the element reverses itself and its resistance increases as temperature and relative humidity decrease. This reversal feature is inherent in the

design of the element and has been considered in construction of the CP 223( )/UM Humidity-Temperature Computer.

The baroswitch is an integral component of all radiosondes tested and has two functions in the instrument: (1) to indicate pressure values during the sounding, and (2) to switch the temperature, humidity, low reference and high reference resistors into the transmitting circuit in a fixed cyclic order.

The baroswitch as a unit consists of a simple aneroid cell with one side of the pressure diaphragm fixed to a rigid support while the other side causes movement of a contact arm through a linkage. As the sonde passes into levels of lower pressure the diaphragm of the baroswitch distends and moves a contact arm across a commutator bar which, in turn, consists of 150 metallic segments, each separated by a dielectric. Pressure values are determined by determination of the "contact" count and consultation of a factory calibrated chart provided with and serialized for each instrument.

Temperature compensation of the baroswitch is necessary and is provided by fabrication from a special steel alloy and heat-treatment to provide nearly zero thermoelastic effect. According to the manufacturers, [2] "baroswitch component materials have been selected so as to compensate each other in conjunction with the diaphragm".[2] The exactitude of this temperature compensation is a subject for further research and is discussed quantitatively in Section 10.

[2] Instructions for Radiosonde Set AN/AMT-11C (Baltimore: The Bendix Corporation, 1966) p. 6.

Temperature is transmitted while the contact arm engages the dielectric segment of the commutator bar; humidity is transmitted during contact with the metallic segment but is interrupted every fifth contact when it must be sacrificed for a low or high reference segment. This interruption often resulted in the loss of information in a thin layer of water vapor concentration when the commutator switching sequence went from humidity to temperature to reference to temperature to humidity. In several cases a trend toward a relative maximum (or minimum) was observed but its exact value was lost in the 250-meter layer transcended with no relative humidity information. This deplorable feature is inherent in all instruments which utilize baroswitch sequencing devices and its shortcomings are extolled fully in Section 10.

All instruments tested were powered by water-activated batteries. The AMT-11DX carried a type BA-385/AM strapped to the bottom of the transmitter and the AMT-11C used a type BA-353/AM, also mounted externally on the bottom of the transmitter. Type BA-259/AM batteries were carried internally by the AMT-4B transmitters in the compartment constructed for that purpose. Physically, the compartment is located immediately above the transmitter-antenna extension and just below the baroswitch compartment. The hinged door of the battery compartment serves as a mounting plate for the transmitter extension.

An informal experiment was conducted in which an AMT-4B transmitter was assembled for flight, then placed in a freezing compartment with a thermometer inserted through a drilled hole into the battery compartment. After approximately 50 minutes in the freezer at an ambient temperature of -28C the temperature in the battery compartment was approximately 65C. This extremely high value was exceeded later but exact values were

indeterminate since the mercury was driven to the end of its chamber. This simple experiment cast grave doubt on the sagacity of mounting a heat source inside the instrument and more careful experiments were conducted later, the results of which are discussed in detail in Section 11.

3. Batteries.

Three types of batteries were used: (1) BA-385/AM with the AMT-11DX, (2) BA-353/AM with the AMT-11C, and (3) BA-259/AM with the AMT-4B. (1) was manufactured by the Eagle-Picher Corporation, Joplin, Missouri, (2) by Ray-O-Vac Division, Wonewoc, Wisconsin, and (3) by Eagle-Picher and Ray-O-Vac.

In research conducted by Caron[7] various battery activants were used in place of water in an attempt to determine non-freezing solutions which would permit longer battery life at extremely cold temperatures. Activants used were tap water at temperatures of 30C and 49C, water solutions of alcohol, glycerine, and "Prestone", and sea water. All activants other than water were used at 23C (room temperature) and served to decrease activation time but also battery life. Caron's efforts suggest that since rapid activation decreases battery life, efforts to hasten battery activation should be discouraged. As a step in the reverse direction, distilled water at near freezing temperature is suggested as a catalyst.

All batteries used in radiosonde flights were activated by tap water at room temperature. The activation times varied to a greater and lesser extent than those recommended by the manufacturers but the best results were obtained from explicit compliance with the manufacturers' instructions. The greatest deterrent to long life in the BA-259/AM was found to be connecting the battery to the transmitter prior to the prescribed 25-minute lapse from starting time. Premature connection to the test load appeared to induce shorter battery life also, but to a lesser extent than premature use.

No test loads as prescribed for the BA-385/AM and BA-353/AM were available and both types were connected to the transmitter at the time prescribed for connection to a test load. Voltage outputs were determined by a multimeter and baseline ground calibration procedures commenced when the prescribed test-load time had lapsed. While not ideal, this procedure seemed satisfactory.

The BA-385/AM batteries were configured with a resistor of unknown value in the series circuit of the battery. The first three flights had constant reference drift (low reference contact drifted to the right of the 95th ordinate value used in ground calibration) with sounding number one having been terminated due to a drift beyond correctable values. Fortunately, the radiosonde supervisor had had similar experience elsewhere and his discovery of the series resistor resulted in its removal from the battery circuit. The succeeding flight passed through the two-millibar level so the suspect resistor was removed from the battery on all but two of the subsequent AMT-11DX flights. This step was inadvertly omitted from the ground procedures for flights ten and seventeen, both of which terminated at low altitude (11.9 and 15.1 km, respectively) with excessive reference drift.

Fourteen of the 35 soundings that used the BA-385/AM battery terminated due to either fading or complete cessation of the signal. Ten of the 14 soundings did not reach the ten-millibar level. Discounting sounding number 51 which was abandoned, 11 of the 15 soundings which were powered by the BA-353/AM terminated in a fading signal, six of which did not reach the ten-millibar level. Percentage-wise, this constitutes premature signal failure for 28.6 percent of the BA-385/AM soundings and for 40.0 percent of the BA-353/AM soundings. In the same

environment, only 4.0 percent of the BA-259/AM soundings terminated below the ten-millibar level due to signal loss.

While it was not the intent of the conducted research to perform a quality control check of manufacturers' battery products, it was inevitable that battery failures would evidence themselves. A thorough knowledge of the upper stratosphere will be attainable only when the ten-millibar level is accurately sounded on a routine basis with a significant number of soundings terminating at or above the two-millibar level, and no potential deterrent from this goal can be safely overlooked. Therefore, battery design for the AMT-11 series transmitters should be the subject of continued research.

4. Balloons.

General purpose 1200-gram neoprene balloons, manufactured by The Kaysam Corporation of America, Paterson, New Jersey, were used for all soundings. The quality of fabrication seemed exceptionally well controlled since only two of the 106 (51 soundings plus one abort for a total of 104 inflated) unpackaged were rejected during the inflation process.

Conditioning of the balloons was achieved primarily in an oven approximately 1.5 cubic feet in size heated by a 60-watt electric light bulb. Oven temperature remained relatively constant at 35C. Temporary use of a thermostatically controlled incubator led to trial of higher temperatures, but the results achieved were inferior to those resulting from the use of unconditioned balloons. Incubation at 35C for a duration greater than 24 hours also resulted in inferior performance. Soundings 31, 32, and 35 were borne aloft on balloons which had been in the oven at 35C for 48 hours and they terminated due to ballon burst at nominal altitudes of 15, 16, and 21 kilometers, respectively.

Relative humidity is also a factor in balloon conditioning but no control of this parameter could be attained and no records were kept concerning its values. However, it normally ranged from 50 to 75 percent.

Extreme care was used in balloon handling since normal fingertip perspiration has a deteriorating effect on the thin neoprene envelope. Balloons were spread over a large, clean acetate prior to inflation with all necessary handling having been accomplished through the plastic container in which the balloons were packaged. Care was exercised to handle balloons only by the nozzle and the thicker balloon top with the nozzle having been the only portion touched directly.

Two balloons were used for each flight and each was inflated sufficiently to support 2,000 grams. The complete train had a nominal weight of 1,900 grams and equal sharing of the load resulted in 1,050 grams of free-lift for each balloon. This figure is in the lower range of optimum free-lift prescribed in the Manual of Radiosonde Observations[3] and resulted in an ascension rate of 235 to 250 meters per minute to the 400-millibar level using the train configuration shown in Figure 1.

Occasionally the inflated balloons had different shapes and equal load sharing did not take place, resulting in ascension rates less than 200 meters per minute. Improvement was attempted by connecting the balloons in tandem with the lower balloon slightly over-inflated. (See inset, Fig. 1) Sounding number seven was the first to use this balloon arrangement and it reached an altitude of 36,689 meters with an average ascension rate of 349 meters per minute. One balloon burst at that altitude and the remaining balloon with its train (including remnants of bursted balloon) was in near neutral bouyancy with its environment. This phenomenon resulted in an extremely interesting but unuseable temperature record. Similar records were obtained from other soundings which terminated due to a floating balloon and Section 12 is devoted to discussion of the features noted.

Inspiration received from the successful flight of sounding number seven led to similar balloon arrangements for flights eight and nine. Both of these latter soundings terminated due to the premature bursting of one balloon and a slow descent, so the parallel configuration was resorted to for the remainder of the flights.

[3] Manual of Radiosonde Observations (Washington: U. S. Government Printing Office, 1957) pp. 102-3.

Whenever sufficient personnel and sky cover permitted the ascension was followed by a theodolite and the balloons were never observed to contact each other during flight. However, severe contact was often made during the launching procedure and is almost certain to have caused a shorter life for one or both of the balloons.

Including the three soundings taken on the tandem arrangement as well as those which utilized over-conditioned balloons, 26 percent of the total (13 soundings) terminated due to balloon burst below the ten-millibar level. Operationally speaking, this is not an acceptable quota of high altitude soundings. However, removal of the six soundings which were pre-destined to terminate prematurely, due either to their flight arrangement or conditioning, changes the balloon failure percentage to 12 percent. Further subjective modification can be made to the failure percentage figure through the well grounded postulation that two balloons experiencing violent contact during launching have a shorter life expectancy than does a properly handled balloon launched singly.

A. U. S. Naval ship in support of operations at the Pacific Missile Range, Point Mugu, California, utilizes Kaysam manufactured 1200-gram balloons and sounds the ten-millibar level routinely, considering any flight which does not reach that level a failure. Therefore, it would seem that sufficient balloon quality can be achieved to the extent that, with proper preparation and ground-handling, balloons will not be a factor in low altitude sounding termination, where "low" can be considered a value less than 30 kilometers.

5. General Comparison of Sounding Records.

The postulation that radiosonde equipment in current use does not give a true representation of the temperature-relative humidity atmospheric profile is lent credence by reference to Appendix I, in which the surface to 700-millibar layers of soundings 36 through 50 are presented graphically. These particular soundings were chosen for inclusion because the AMT-11C transmitter was slightly more compatible with the AMT-4B than was the AMT-11DX and minimum difference in respective flight records can be expected. Further, these soundings were taken through a strong temperature inversion, and the fact that in no cases did the two instruments describe the inversion in exactly the same way is considered of academic interest.

In determining the profiles, temperature and relative humidity were evaluated at one-minute intervals with significant points selected between the one-minute intervals such that the plotted curves do not differ by more than 0.5C and 5 percent from the actual traces of temperature and relative humidity, respectively. (The Manual of Radiosonde Observations[4] prescribes 1.0C and 10 percent as the determining criteria for significant levels).

Tables I and II afford a ready comparison of significant meteorological parameters obtained from each flight record along with the maximum altitude at which useable data were transmitted. The legend for the "Reason for Termination" and other tabulated entries is as follows:

SFC:	Maximum occurred at the SFC
NR:	Did not reach minimum temperature level
ERD:	Excessive reference drift resulted in unusable data

[4] Manual of Radiosonde Observations (Washington: U. S. Government Printing Office, 1957) pp. 121-27.

TABLE I
Significant Parameters Obtained from the Records of Flights 1 Through 35
1 December 1965 to 10 May 1966

Sounding No.	Maximum Altitudes (m)		Maximum Rel. Hum. (%)		Maximum Temperature (°C)		Minimum Temperature (°C)		Reason For Termination	
	AMT-11DX	AMT-4B	AMT-11DX	AMT-4B	AMT-11DX	AMT-4B	AMT-11DX	AMT-4B	AMT-11DX	AMT-4B
1	27376	38995	65	62	13.6	13.0	-69.5	-68.0	ERD	BB
2	26169	25106	SFC	SFC	20.3	20.0	-67.2	-65.7	FB	FB
3	17586	18097	61	58	15.7	15.7	-66.8	-63.6	FB	FB
4	42004	31828	88	100	SFC	SFC	-64.0	-60.8	150	SS
5	32159	29798	42	49	14.4	13.4	-68.9	-64.5	FB	FB
6	15808	30402	57	64	10.6	11.3	NR	-63.8	SS	BB
7	29532	36689	82	100	SFC	SFC	-71.8	-63.1	SF	FB
8	22937	22848	84	100	SFC	SFC	-73.0	-66.8	BB	BB
9	29651	29086	64	73	SFC	SFC	-66.2	-60.8	BB	BB
10	11906	36657	80	92	SFC	SFC	NR	-62.6	ERD	BB
11	27100	38797	66	57	17.7	16.8	-77.7	-69.5	SF	SF
12	15462	36429	83	88	9.9	8.7	-68.2	-65.2	SF	SF
13	36780	37252	48	45	13.9	13.9	-72.8	-70.9	SF	SF
14	43339	36951	65	57	13.7	13.9	-64.6	-61.8	SF	SF
15	40603	30582	81	73	SFC	SFC	-64.6	-59.4	SF	SF
16	42393	41838	65	67	SFC	SFC	-61.9	-60.5	BB	SF
17	15093	28208	75	81	9.5	9.2	NR	-61.7	ERD	BB
18	16900	16842	68	82	SFC	SFC	-62.3	-60.9	BB	BB
19	9717	18740	78	85	SFC	SFC	NR	-61.2	SF	BB

20	18393	6331	77	100	SFC	SFC	NR	NR	SF	TC
21	25647	33984	73	79	SFC	SFC	-61.0	-59.3	SF	SF
22	42075	29672	73	75	SFC	SFC	-58.8	-56.1	150	SF
23	22987	28205	71	73	SFC	SFC	-68.0	-66.5	SF	SF
24	23227	23150	71	77	9.5	9.4	-65.1	-62.1	BB	BB
25	35597	39077	SFC	SFC	11.7	SFC	-69.3	-65.5	BB	BB
26	31030	35337	MSG	72	16.7	16.4	-68.9	-67.8	BB	BB
27	31084	32622	83	100	SFC	SFC	-67.3	-66.4	BB	BB
28	40164	31808	62	68	7.9	SFC	-65.5	-63.8	SS	SF
29	14160	14983	74	78	SFC	SFC	-67.4	-65.8	GEF	BB
30	32244	30210	74	98	SFC	SFC	-69.7	-68.3	FB	SF
31	15189	15044	79	84	SFC	SFC	-67.0	-66.0	BB	BB
32	16281	16018	SFC	SFC	21.0	22.6	-67.6	-65.5	BB	BB
33	7412	36878	85	100	21.8	21.9	NR	-62.3	SF	EOC
34	38619	30661	90	92	SFC	SFC	-62.6	-62.1	BB	SF
35	21868	22153	85	87	SFC	SFC	-62.5	-61.0	SF	BB

TABLE II
Significant Parameters Obtained from the Records of Flights 36 through 50
18 July through 22 July 1966

Sounding	Maximum Altitudes (m)		Maximum Rel. Hum. (%)		Maximum Temperatures (°C)		Minimum Temperatures (°C)		Reason For Termination	
No.	AMT-11C	AMT-4B	AMT-11C	AMT-4B	AMT-11C	AMT-4B	AMT-11C	AMT-4B	AMT-11C	AMT-4B
36	23089	23151	55	86	20.8	21.6	-64.2	-63.7	SF	BB
37	42994	32918	80	75	22.6	23.2	-66.2	-65.5	SF	SF
38	15622	9630	82	85	21.5	21.2	-65.3	NR	SF	GEF
39	40161	20384	88	88	22.0	21.4	-67.1	-66.7	EOC	GEF
40	38107	36693	78	71	22.0	22.2	-66.0	-65.1	EOC	SF
41	14930	31627	87	100	20.8	20.9	NR	-67.7	SF	SF
42	26952	27152	87	100	23.0	22.1	-68.0	-67.3	BB	BB
43	18834	31195	81	82	23.6	22.9	-66.4	-64.9	SF	SF
44	37901	36666	88	100	23.2	22.7	-68.0	-66.6	SF	SF
45	20887	22032	82	SFC	25.5	24.6	-68.5	-67.6	SF	GEF
46	28538	30524	65	72	26.1	26.3	-68.3	-67.7	SF	SF
47	32252	10657	76	57	25.0	25.6	-69.5	-67.2	SF	GEF
48	36448	35966	84	84	25.0	25.5	-68.3	-67.3	SF	SF
49	37861	37305	94	94	25.0	25.2	-67.5	-66.4	SF	SF
50	27246	26665	84	100	23.6	23.8	-70.1	-69.3	BB	BB
51*	18641	18913	82	100	24.2	23.7	-66.8	-65.8	Abandoned	

*No. 51 was an experimental flight using a modified AMT-4B temperature circuit and is discussed in detail in Section 6.

BB:	Balloon burst
FB:	Floating balloon (occurred when one balloon burst)
150:	150th contact reached
SS:	Signal stopped (abruptly)
SF:	Signal faded (usually accompanied by noise)
TC:	Transmission of temperature values ceased.
GEF:	Ground equipment (receiver) failure
EOC:	End of calibrated portion of chart reached

The maxima and minima points listed in Tables I and II are not only meteorologically significant in any sounding but of particular importance here because they are points at which the least difference between the two instruments can be expected since the points themselves were selected without regard to time or pressure. For example, there is one point in the soundable layer of the atmosphere at which the temperature is colder than at any point immediately above or below it (this "point" is occasionally an isothermal layer). As each instrument passed through this point it should have indicated a minimum temperature which agrees precisely with the minimum temperature indicated by the accompanying instrument which was separated horizontally by a distance of one meter. Whether the instruments agreed as to the pressure at the level of minimum temperature was not taken into account here but is a subject of discussion in Section 10.

The maxima and minima data listed by sounding number in Tables I and II were evaluated statistically and the results are depicted in Tables III, IV, and V. Sounding 51 carried an experimentally configured temperature circuit and is not included in these statistics. Table III was computed by subtracting the maximum relative humidity values recorded by the AMT-11DX and AMT-11C transmitters from the respective maxima recorded by the AMT-4B, then computing the mean of the differences (not presented) and the standard deviations from the means, where standard

deviation is defined as the deviation from the mean in a normal distribution such that 68 percent of the deviations will be less than or equal to the standard deviation.

TABLE III

DIFFERENCE BETWEEN POINTS OF MAXIMUM RELATIVE HUMIDITY

Transmitter Combination	Standard Deviation (%)	Range (%)	Percentage with differences less than 5%	Percentage with differences less than 10%
4B-11DX	8.17	-9 to 24	35.5	73.2
4B-11C	7.29	-7 to 16	50.0	66.7

NOTE: Transmitter Combination should be interpreted as follows: 4B-11DX means AMT-4B maxima minus AMT-11DX maxima.

The magnitude of the differences is the important parameter but as the ranges suggest, the AMT-4B maxima were usually the greater value, exceeding the AMT-11DX maxima in 25 of the 31 soundings where maxima were observed and the AMT-11C maxima in 10 of the observations.

Table IV entries were computed by subtracting the AMT-4B maximum temperatures from the AMT-11DX and AMT-11C maxima. Again the means of the differences and the standard deviations from the means were computed.

TABLE IV

DIFFERENCES BETWEEN POINTS OF MAXIMUM TEMPERATURE

Transmitter Combination	Standard Deviation (C)	Range (C)	Percentage with differences less than 1.0C	Percentage with differences less than 2.0C
11DX-4B	0.69	-1.6 to 1.2	85.7	100
11C-4B	0.50	-0.8 to 0.9	100	100

NOTE: Transmitter Combination should be interpreted as follows: 11DX-4B means AMT-11DX maxima minus AMT-4B maxima

In ten of the fourteen cases where both instruments recorded a maximum temperature (not at the surface), the AMT-11DX indicated a higher value than did the AMT-4B. Further, the AMT-11DX recorded maxima in soundings 25 and 28 which were not observed on the records of the AMT-4B transmitters. These maxima were not included in the tabulated computations because they occurred while the AMT-4Bs were transmitting a pressure reference portion of the contact causing their failure to observe a slight inversion near the surface. The AMT-11C soundings were taken through a very sharp inversion and the maximum temperatures recorded by the AMT-4B exceeded those recorded by the AMT-11C in nine of the fifteen observations. In the latter instance, all differences were less than 1.0C.

Table V entries were computed by subtracting the minimum temperatures recorded by the AMT-11DX and AMT-11C transmitters from the minima recorded by the AMT-4B transmitters. Since the former exceeded the latter in a negative sense in all observations the differences obtained are positive values, hence the positive entries for range.

TABLE V

DIFFERENCE BETWEEN POINTS OF MINIMUM TEMPERATURE

Transmitter Combination	Mean (C)	Range (C)	Percentage with differences less than 1.0C	Percentage with differences less than 2.0C
4B-11DX	2.59	0.1 to 8.7	16.1	54.8
4B-11C	1.09	0.4 to 2.3	57.1	92.8

NOTE: Transmitter Combination should be interpreted as follows: 4B-11DX means AMT-4B minima minus AMT-11DX minima.

Since all differences are of the same sense, the mean acquires significance and was included in lieu of standard deviation. These latter

values were computed, however, and if tabulated would read 2.04 and 0.43 (top to bottom). The range of the differences was significantly less when the AMT-11C transmitters were flown. However, these soundings were launched in July when the average minimum temperature (of the AMT-11C) was -68.0C. The AMT-11DX transmitters were flown in the winter and early spring, primarily, and the largest temperature differences occurred on those flights where the AMT-11DX recorded temperatures colder than -70.0C, (soundings 7, 8 and 11, Table I). Soundings 24 and 28 were the only two AMT-11DX nighttime flights which resulted in both transmitters recording temperature minima and the differences noted were 3.0C and 1.7C, respectively. With one value greater than the mean and the other less, no intelligent conclusion can be drawn from them concerning solar effects on the instruments. AMT-11C soundings 44 and 47 were nighttime flights in which both instruments recorded minimum temperatures and the respective differences are 1.4C and 2.3C. Both values exceed the mean difference, suggesting that direct solar radiation has more effect on the AMT-4B temperature element than it does on the AMT-11C element. However, the limited number of observations prohibits a firm conclusion in this respect.

Sounding 48 was launched at 1520, 26 July 1966, PDT and number 49 was launched at 1900 the same day. Both instruments recorded a warmer minimum temperature on the later sounding with the minimum occurring at 1959 on the AMT-4B record and at 1959 plus 24 seconds on the AMT-11C record. Minimum temperatures were reached on both soundings at a nominal altitude of 15,600 meters. Sunset occurred at 2017 PDT, hence the solar angle was very low at the time of minimum temperature.

Since the angle at which the sun's rays reaches the temperature

element undoubtedly has an effect on the amount of insolation received, radiosonde temperature accuracy could be improved by a systematic study of the atmosphere at short time intervals commencing before dawn and terminating after sunset. This would permit determination of a temperature correction factor which could then be applied to the observed temperatures with the correction factor itself a variable dependent on time of day, time of year, latitude, and altitude.

Standard radiation corrections are made to radiosonde observations but as Craig[1] very aptly states "meteorologists using the data find it necessary to make additional empirical corrections based on the observed differences between nighttime and daytime soundings".[5] With a 0.8C change (AMT-11C) having occurred in a time interval of three hours and forty minutes, empirical corrections based on soundings which are operationally taken at twelve-hour intervals hardly seem adequate. Precise correction factors must be determined before the atmospheric temperature profile can be accurately evaluated.

[5]Richard A. Craig, The Upper Atmosphere Meteorology and Physics (New York and London: Academic Press, 1965) p. 20.

6. Error Analysis of Meteorological Parameters at Standard Pressure Levels.

The data obtained from soundings one through 50 were coded for reduction by a Control Data Corporation Model 3100 Computer. The format used for data card entry is that described in Appendix II and all soundings were reduced by Elliott M. Davies, AGCM, USN, at the Geophysics Division, Pacific Missile Range, Point Mugu, California. The soundings were also reduced graphically on the WBAN-31 series adiabatic charts, but to obtain differences which were influenced as little as possible by human error, the computer print-out values were used in determining the tabular entries in this Section. The graphical reductions were performed in order to effect a comparison between the computer and the graphical products and discussion of the results of this comparison is deferred until Section 13.

The parameters whose differences were evaluated at standard pressure levels are independent variables. This important fact cannot be overemphasized since a multitude of possibilities, any one of which can account for a particular difference noted, exists. The simplest possibility is presented as an example. In sounding number one the 25-millibar temperature determined from the AMT-11DX record is -56.2C. The corresponding temperature determined from the AMT-4B record is -57.7C. The factors, any one of which could have contributed to this 1.5C difference are (1) one or both temperature elements were in error, (2) one or both baroswitches indicated erroneous pressure levels, and (3) both (1) and (2). This does not include any errors in ground calibration which would have been evidenced by a systematic bias nor does it include the possibility of error in flight record interpretation.

Included also are the resultant differences in the derived parameters of dew point and pressure-altitude. These values depend not only on the pressure values determined from the calibration chart but also on the directly measured values of temperature and humidity. Little imagination is required to realize that the source of errors present in dew point and pressure-altitude calculations is greatly increased over that for directly measured parameters.

TEMPERATURE

At standard pressure levels from 1000 to 4 millibars the AMT-11DX and AMT-11C temperature values were subtracted from the corresponding AMT-4B values. The mean of the differences and the standard deviation from the mean were calculated and tabulated in Tables VI and VII respectively. To reduce error and for ease in calculation, all arithmetical processes were done on a CDC 1604 computer. AMT-11DX and AMT-11C data were subtracted from the AMT-4B values in all cases in order to systemize, if possible, the differences noted. Using this scheme, a negative mean value indicates that, in the mean, the AMT-11C temperatures were warmer than those of the AMT-4B, and conversely, a positive mean indicates that the AMT-11C temperatures were colder than those of the AMT-4B. The mean of the differences by itself is not always significant since it can take on a zero or near-zero value with large deviations in both directions with a near-zero difference seldom, if ever, having occurred. In those cases where the mean and the standard deviation are both small, reasonable assurance exists that the elements were both operating within the prescribed tolerance of 1.0C. Unfortunately, those cases are few.

TABLE VI

TEMPERATURE COMPARISON AT STANDARD PRESSURE LEVELS
AMT-4B and AMT-11DX

Pressure (mb)	Mean (C)	Standard Deviation (C)	Range (C)	Number of Observations
1000	0.05	0.87	-2.7 to 2.4	35
850	-0.13	0.69	-2.6 to 1.2	35
700	-0.40	0.80	-2.6 to 1.1	35
500	-0.14	1.15	-1.9 to 3.2	35
400	0.99	0.87	-1.6 to 2.9	34
300	1.56	1.28	-0.8 to 5.7	33
250	1.79	1.07	0.0 to 4.3	31
200	1.76	1.33	-0.1 to 5.0	31
150	1.70	1.55	-1.1 to 6.0	31
100	1.81	2.13	-0.3 to 8.8	25
50	1.67	1.78	-0.5 to 7.4	23
30	1.89	2.28	-1.8 to 7.5	19
20	1.03	3.47	-9.9 to 6.0	17
15	1.55	1.79	-1.9 to 4.7	15
10	-0.40	3.82	-9.1 to 4.8	9
7	-0.85	1.31	-2.8 to 0.4	4
5	-0.35	0.60	-1.0 to 0.6	4
4	0.43	0.69	-0.4 to 1.3	3

TABLE VII

TEMPERATURE COMPARISON AT STANDARD PRESSURE LEVELS
AMT-4B and AMT-11C

Pressure (mb)	Mean (C)	Standard Deviation (C)	Range (C)	No. of Observations	Sounding No. 51
1000	0.30	0.83	-1.4 to 1.7	15	-0.1
850	0.21	0.50	-1.1 to 1.2	15	-0.1
700	0.55	0.47	0.0 to 1.3	15	-0.8
500	-0.04	0.45	-0.8 to 0.7	15	-0.1
400	0.20	0.58	-1.0 to 1.0	15	-0.5
300	0.64	0.45	-0.2 to 1.6	13	0.2
250	0.08	0.43	0.1 to 1.7	13	0.2
200	1.12	0.49	0.2 to 1.9	13	0.3
150	0.52	0.35	0.0 to 1.2	13	-0.3
100	0.53	0.74	-0.6 to 2.3	12	1.4
50	1.38	1.04	-1.2 to 2.9	10	
30	2.70	1.83	1.2 to 7.2	8	
20	1.67	1.61	-1.1 to 3.5	7	
15	2.98	1.90	1.6 to 6.7	5	
10	3.00	1.83	0.8 to 5.9	5	
7	1.73	1.80	-0.1 to 4.5	4	
5	3.97	2.74	1.6 to 7.8	3	

Analysis of Tables VI and VII entries suggests, quite correctly, that the AMT-4B transmitters indicated temperatures which were mostly warmer than those recorded by the AMT-11DX, and although to a lesser degree, warmer than those indicated by the AMT-11C. Except for minor differences in size, the temperature sensing elements used in all radiosondes tested were essentially the same, therefore, the systematic bias in the differences must lend itself to a physical and presumably correctable discrepancy in the equipment configuration and/or the element fabrication.

It was on this premise that the simple experiment with the battery compartment temperatures discussed in Section 3 was conducted, with the theory projected that heat given off by the battery had had a warming effect on the temperature elements of the AMT-4B transmitters. In an effort to determine the significance of this effect, if indeed it did exist, an AMT-4B transmitter was slightly reconfigured to place the temperature sensing element 70 centimeters below the transmitter and its associated heat source. Sounding 51 was launched carrying this reconfigured transmitter and an AMT-11C transmitter at an ascension rate of 192 meters per minute. The AMT-4B still did not indicate as cold a temperature as did the AMT-11C, but the differences from the 300-mb level to the top of the sounding were considerably less than the calculated means at the same levels using standard equipment.

Since the best agreement between the temperature elements in general was obtained in the lower, warmer layers, a gross difference of -1.7C at 950 millibars (not shown in Table VII) can be attributed solely to a disagreement in the pressure level sensed by the baroswitch and is not due to temperature element error. Another gross difference occurred

at the 100-mb level and cannot be explained as lightly. The level of minimum temperature was described as a point at 120 millibars by the AMT-4B and as an isothermal layer from 118 to 113 millibars by the AMT-11C. A relatively slow ascension rate was used to avoid this specific event, obviously with no degree of success. The net result was that the AMT-4B element, upon indicating its minimum point, reversed its trend and recorded warmer temperatures immediately, resulting in a 1.4C difference at the 100-millibar level, a value in excess of the difference recorded at the minimum temperature of the sounding. This difference can be attributed in part to the disagreement between the baroswitches concerned but not entirely, since the AMT-11C indicated only 1.5 millibars less pressure at the 100th minute than did the AMT-4B and the lapse rates were nominally 0.3C temperature increase per 1.5 millibars pressure decrease for both instruments.

Except for the discrepant values noted at 950 and 100 millibars and at the minimum temperature level, the modified AMT-4B transmitter recorded values which were generally in quite good agreement with the AMT-11C, particularly at the higher levels where greater magnitude of differences had occurred.

One sounding does not constitute a foundation upon which firm conclusions can be based; it does, however, open an avenue of further research. Since the AMT-4B transmitters with the ML-419 temperature elements in no case recorded as cold a temperature as did the AMT-11 with the ML 405/AM elements, the ML-419 is highly suspect to having been affected by transmitter temperature and to poor response in the lower temperature ranges. Data have not been analyzed for differences as a function of indicated temperature, per se, but a general range is available in Tables VI and

VII, using the over-all guideline that temperature decreases with height, and recalling that in the summer soundings 36 and 51 the colder temperatures occurred at greater heights than did those of the winter soundings.

RELATIVE HUMIDITY

Relative humidity is a directly measured parameter but the sensing elements used in AMT-4B transmitters are of entirely different characteristics than are those of the AMT-11 transmitters, the former having a carbon-coated element whose resistance increases as sensible water vapor increases and the latter a lithium-chloride coated element whose resistance decreases as water vapor increases. The elements were observed to indicate the amount of water vapor present as greatly different values.

Reference to Tables VIII and IX reveals the general differences to be biased toward higher values on the part of the AMT-4B.

TABLE VIII

RELATIVE HUMIDITY COMPARISON AT STANDARD PRESSURE LEVELS
AMT-4B and AMT-11DX

Pressure (mb)	Mean (%)	Standard Deviation (%)	Range (%)	Number of Observations
1000	-1.24	5.39	-19 to 7	34
900	3.88	6.91	-10 to 26	34
800	3.09	8.92	-18 to 21	33
700	3.18	7.31	-15 to 21	34
600	2.88	8.97	-27 to 24	34
500	5.39	9.86	-24 to 21	33
400	3.97	13.74	-25 to 45	32
350	3.29	10.36	-18 to 22	21

In the above table as well as in Table IX, AMT-11 humidity values were subtracted from the corresponding AMT-4B values. With the exception of the 1000-mb entry in Table VIII this scheme resulted in positive mean values for the obtained differences. Sounding 51 has not been

included in Table IX because it was reduced graphically only and its inclusion would have introduced a human element into the comparison which is otherwise absent.

TABLE IX

RELATIVE HUMIDITY AT STANDARD PRESSURE LEVELS
AMT-4B and AMT-11C

Pressure (mb)	Mean (%)	Standard Deviation (%)	Range (%)	Number of Observations
1000	4.36	7.49	-7 to 22	14
900	5.29	9.17	-17 to 21	14
800	9.29	8.07	-1 to 24	14
700	6.07	9.80	-16 to 24	14
600	6.93	7.54	-9 to 26	14
500	7.79	6.49	-2 to 22	14
400	4.93	5.85	-4 to 19	14
350	4.29	5.74	-5 to 18	14
300	3.85	5.20	-5 to 14	13

While the AMT-4B temperature element displayed a visible reluctance to indicate very low temperatures, the ML-379/AM lithium-chloride humidity element used with the AMT-11 transmitters evidenced an equal reluctance to indicate very high humidity values, never having reached 100 percent and having exceeded 90 percent in only one instance. Several of the soundings were taken through a thick stratus layer which produced a light mist at the surface, and saturation with respect to water vapor was undoubtedly an existent condition through the stratus.

On the lower end of the scale, while the AMT-11 transmitters telemetered a "motorboating" signal, indicating the humidity to be approximately ten percent, the AMT-4B recorded values ranging from 20 to greater than 30 percent. In those cases where motorboating occurred, statistical "maximum possible" values were used for the AMT-11 data reduction.

These statistical maxima were usually exceeded by the AMT-4B corresponding values.

All of the soundings 35 through 50 experienced a pronounced moisture decrease immediately above the temperature inversion (See Appendix I) which was recognized by both transmitters. However, the AMT-4B, with the exception of sounding number 47, continued to indicate the presence of water vapor. In number 47, the AMT-4B recorded humidity values of zero and is considered to have had an inoperative element, hence its humidity values were not used in calculating the entries for Table IX.

No method of proving or disproving either humidity value as correct is presently available. The calculated statistical parameters do lend themselves to qualitative analysis, however, particularly when considered in conjunction with the varying synoptic situation.

Ascent through a thick cloud layer should have produced a humidity record which indicates atmospheric saturation through the layer. Therefore, the ML-476 carbon element is believed to have been accurate in reporting 100 percent relative humidity as it passed through the stratus. Its complete credibility is questionable, however, since in all cases in which saturation was reached, the recorded values, when converted to relative humidity, exceeded the upper limit (100%) of the humidity scale on the CP223A/UM computer.

On the lower end of the scale the AMT-4B carbon element is considered to have been in error. Minimum difference were noted in the mid-range humidity values.

DEWPOINT

Dewpoint is a derived parameter and, while its value at a particular

isobaric level is partially dependent upon the accuracy of the baroswitch, it is more directly dependent upon the reported values of temperature and relative humidity. No new insight concerning the accuracy of the radiosondes can be achieved through presentation of dewpoint differences but they have been included because dewpoint, not relative humidity, is the moisture parameter which is encoded and transmitted, eventually to be plotted and analyzed.

The statistical entries in Tables X and XI were derived by employment of the same general procedures outlined for Tables VI and IX.

TABLE X

DEWPOINT COMPARISON AT STANDARD PRESSURE LEVELS
AMT-4B and AMT-11DX

Pressure (mb)	Mean (C)	Standard Deviation	Range (C)	Number of Observations
1000	-0.21	2.11	-5.1 to 6.9	33
900	1.53	3.40	-2.0 to 3.4	34
800	1.42	3.59	-6.6 to 10.1	33
700	1.08	3.27	-4.9 to 9.4	34
600	0.65	2.98	-6.1 to 8.8	34
500	2.13	3.58	-7.9 to 8.3	33
400	2.31	3.65	-6.1 to 11.9	32
350	2.08	2.64	-3.1 to 6.8	21

TABLE XI

DEWPOINT COMPARISON AT STANDARD PRESSURE LEVELS
AMT-4B and AMT-11C

Pressure (mb)	Mean (C)	Standard Deviation	Range (C)	Number of Observations
1000	1.11	2.03	-3.0 to 4.7	14
900	3.75	6.42	-12.4 to 13.4	14
800	5.94	4.52	0.2 to 14.9	14
700	5.85	3.03	-1.8 to 12.3	14
600	4.19	4.12	-4.9 to 13.4	14
500	4.10	2.94	-0.8 to 10.0	14
400	2.31	2.43	-2.2 to 7.5	14
350	2.42	2.28	-1.5 to 7.1	14
300	1.77	2.00	-1.6 to 4.8	13

Little perusal is required to realize that encoded values of dewpoints are highly suspect of error. An extremely large range of differences was observed at the 900-mb level in Table XI which is due primarily to the rapid changes in relative humidity with height experienced by the sensing elements and relatively poor resolution of pressure values from the calibration chart. With a relative humidity decrease of 50 percent per ten millibars pressure change,a two-millibar error by either baroswitch would have resulted in a ten percent humidity difference at any point within the ten-millibar stratum. As in the humidity evaluation, the positive sign of the mean values coupled with the bias toward positive values in the ranges serves to emphasize the general indication of higher values of humidity by the AMT-4B than by the AMT-11.

A point not emphasized in the relative humidity sub-section but of considerable importance is the range of reportable values when the instruments are in a dry atmosphere. All values from 500 mb through 300 mb in Table XI are derived from data based on a motorboating AMT-11C humidity signal. These values would normally be encoded as missing and the analyst would be left to his own conclusions. The corresponding AMT-4B humidity records resulted in codeable dewpoint values which would have indicated a higher moisture content. The nominal range of the dewpoints for the 500-mb level of soundings 36 through 50 is -29C to -31C which correspond to a mixing ratio value of 0.7 grams per kilogram. This latter value is admittedly not large but is considerably different from "missing".

PRESSURE-ALTITUDE

Pressure-altitude values are used as the basic analytical parameter in determining the synoptic atmospheric pressure patterns and winds.

Accuracy in reporting their values is tantamount to success in achieving an accurate synoptic analysis and forecast.

Accuracy in pressure-altitude computation hinges primarily upon accurate temperature measurement and to a lesser extent on accurate relative humidity values. Precision of the baroswitch is a further requirement which becomes more important at high altitudes where a small pressure difference occurs over a large thickness. The cumulative effects of a 1C temperature error and a pressure measurement error of 3 millibars up to 100 mb and 1.5 mb error above 100 mb are shown in Table XII for some of the standard pressure levels. An average atmosphere was assumed in the calculations.

TABLE XII

Pressure-Altitude Errors of Constant-Pressure Surfaces Due to (1) A Temperature Error of 1C at All Levels and (2) A Pressure Error of 3mb up to 100 mb and 1.5 mb above 100 mb[a]

Pressure Level (mb)	Error Due to Temperature Error (m)	Error due to Pressure Error (m)
100	67	19
50	88	16
25	108	9
10	135	7

[a] From Craig

The Table XII entries clearly indicate that erroneous temperature measurement plays the more important role.

No precise values of pressure-altitude error resulting from erroneous humidity values have been computed but quantitative analysis of a standard temperature curve when plotted on a WBAN-31A adiabatic chart will reveal that a 20 percent humidity error is required to produce a one-meter thickness error over a 100-millibar stratum. Relative

humidity measurement is most accurate in the warmer atmosphere where it has the greater effect on thickness value computations and is not considered to have been an important contributing factor in producing the pressure-altitude differences which are summarized in Tables XIII and XIV.

Discounting the subjective roles of humidity and pressure measurement, the negative mean values from 850 mb through 400 mb in Table XIII show the effects of the AMT-11DX transmitters having recorded the warmer temperature in the lower layers. The positive mean value above 400 mb attest to the AMT-4B having recorded warmer temperatures throughout the upper portion of the ascents. In Table XIV, all mean values are positive and increase with altitude, with the exception of the anomalous 400-mb case, and no negative differences were observed above the 200-mb level.

Comparison of the Table XIII and XIV mean values with the expected errors listed in Table XII suggests that the temperature elements differed in the mean by 1C or less. This suggestion is belied by the fact that as the temperature lapse rate changed sign, thickness errors accrued below an inversion were at least partially cancelled above. This condition of lapse rate sign change occurred at tropospheric inversions and at the tropopause. Indeed, several soundings which resulted in large differences at the lower levels were in quite good agreement near the top of the sounding. A random example of this phenomenon was evidenced by sounding number one in which the two instruments obtained a pressure-altitude difference at 400 mb of 47 meters while at 20 mb the difference was reduced to two meters.

The user still raises the question of confidence limits to be placed in reported pressure-altitudes and his question cannot be dispensed with

TABLE XIII

PRESSURE-ALTITUDE DIFFERENCES AT CONSTANT-PRESSURE SURFACES
AMT-4B and AMT-11DX

Pressure (mb)	Mean (m)	Standard Deviation (m)	Range (m)	Number of Observations
850	-0.5	3.6	-12 to 6	35
700	-1.3	7.7	-27 to 12	35
500	-4.7	16.1	-56 to 35	34
400	-1.5	21.1	-65 to 43	32
300	12.9	33.5	-70 to 118	31
250	25.3	43.9	-72 to 167	31
200	34.1	48.5	-70 to 199	31
150	44.1	47.5	-67 to 159	30
100	67.9	64.2	-64 to 219	24
50	106.2	10.17	-56 to 323	22
30	133.5	136.3	-67 to 402	18
20	152.7	159.7	-76 to 455	16
15	163.6	171.0	-86 to 491	14
10	89.5	139.4	-90 to 372	8
7	40.0	94.1	-83 to 146	4
5	19.3	96.4	-111 to 127	4
4	52.3	97.9	-86 to 126	3

TABLE XIV

PRESSURE-ALTITUDE DIFFERENCES AT CONSTANT-PRESSURE SURFACES
AMT-4B and AMT-11C

Pressure (mb)	Mean (m)	Standard Deviation (m)	Range (m)	Number of Observations
850	1.2	2.5	-2 to 7	15
700	4.4	4.3	-3 to 15	15
500	7.3	8.2	-7 to 26	15
400	2.9	12.4	-27 to 24	14
300	9.7	13.9	-13 to 35	13
250	15.0	14.7	-9 to 40	12
200	22.8	14.9	-2 to 50	12
150	29.4	15.5	3 to 58	12
100	32.0	17.9	2 to 62	11
50	50.0	27.1	5 to 88	9
30	78.0	31.4	20 to 113	8
20	108.2	37.2	34 to 140	6
15	144.2	20.2	112 to 169	5
10	177.8	38.2	131 to 240	5
7	214.5	55.3	157 to 297	4
5	269.0	76.8	176 to 364	3

lightly. Error can be defined herein as the difference between the true value and the reported value and this difference is not immediately obtainable since the true value is unknown. Only a qualitative analysis of the accumulated data can be made.

Again neglecting the effects of pressure measurement and humidity on pressure-altitude computation, one may safely subtract 67 meters from the reported 100 millibar height if that height has been determined by an AMT-4B transmitter. If the atmosphere was sounded by an AMT-11 transmitter the reported height is most probably correct. The foregoing postulations are based on the fact that the AMT-4B exhibited a definite reluctance to record very low temperatures while the AMT-11 transmitters did not. It is further offered without proof that a conductor's resistance is more difficult to increase as very low temperatures are reached and if the resistance is increased, it is safe to assume that the temperature was indeed lowered.

7. Pressure, Temperature, and Relative Humidity Differences at Fixed Time Intervals.

The differences at constant-pressure surfaces discussed in Section 6 provide a perspective on the over-all degree of accuracy to be expected from reported radiosonde values, or said another way, they depict the errors inherent in the total instrumentation.

Since the respective sensing elements could agree only if the baroswitches were in complete accord, or by chance, a comparison of the specific sensing elements involved necessitated a close monitoring of the data purely on a time basis. Comparison at fixed time intervals further provided an accurate estimate of the behavior of the baroswitches.

Since pressure, temperature, and relative humidity values were required at one-minute intervals for the computerized data reduction, this required no additional workload other than the time-sorting of data after it had been reduced as well as complete assurance that the various parameters from the two respective records were recorded at precisely the same time.

The recorder chart drives of both receiver/recorder units feed at a rate of 0.5 inch per minute and by recording values every 0.5 inch the one-minute intervals were easily obtained. However, after sounding number 35 the discovery was made that the total elapsed time of the two records was different in a few soundings. This discrepancy was traced to a faulty gear in the SMQ-1A recorder chart drive which was subsequently replaced. However, while the differences observed amounted to only one or two minutes over a 120-minute sounding, the first 21 carefully timed soundings were not included in the final time comparison since they could not be as precise as was desired. The first 14 soundings were not accurately monitored on a time basis. Omission of the

first 35 soundings reduced the timed sample to 15 observations so that a gain in precision was at the expense of the number of observations. Accuracy, however, was considered of more importance than numbers where the latter is purely for the sake of having a large sample.

PRESSURE DIFFERENCES

By subtracting the AMT-11C pressure value from the corresponding AMT-4B pressure, and averaging all values, a mean difference of -2.0 mb resulted with a standard deviation from the mean of 0.9 millibars. These figures reflect the net of all differences. The mean differences at three-minute intervals were evaluated individually in the same fashion and the results are shown graphically in Figure 2.

The relatively small sample did not result in points which were easily corrected by a smooth curve but the pattern is, nevertheless, rather obvious. The AMT-11 pressure values, in the mean, were greater than the corresponding AMT-4B pressures until after the 63rd minute. From the 63rd minute onward the AMT-11C pressures were the smaller of the two, with the mean difference reaching a quasi-constant value of 1.5 mb at the 84th minute.

The largest mean differences were observed between the 30th and 42nd minutes which was that layer in most soundings over which the lapse rate was very nearly dry adiabatic and the layer in which the AMT-11 frequently indicated short interval superadiabatic lapse rates. The superadiabatic lapse rates apparently resulted from lag in the AMT-11 baroswitch, causing it to indicate a greater pressure value, hence a thinner layer over which the temperature lapse occurred. Andersen,[6] whose experiments are discussed more completely in Section 11, found that

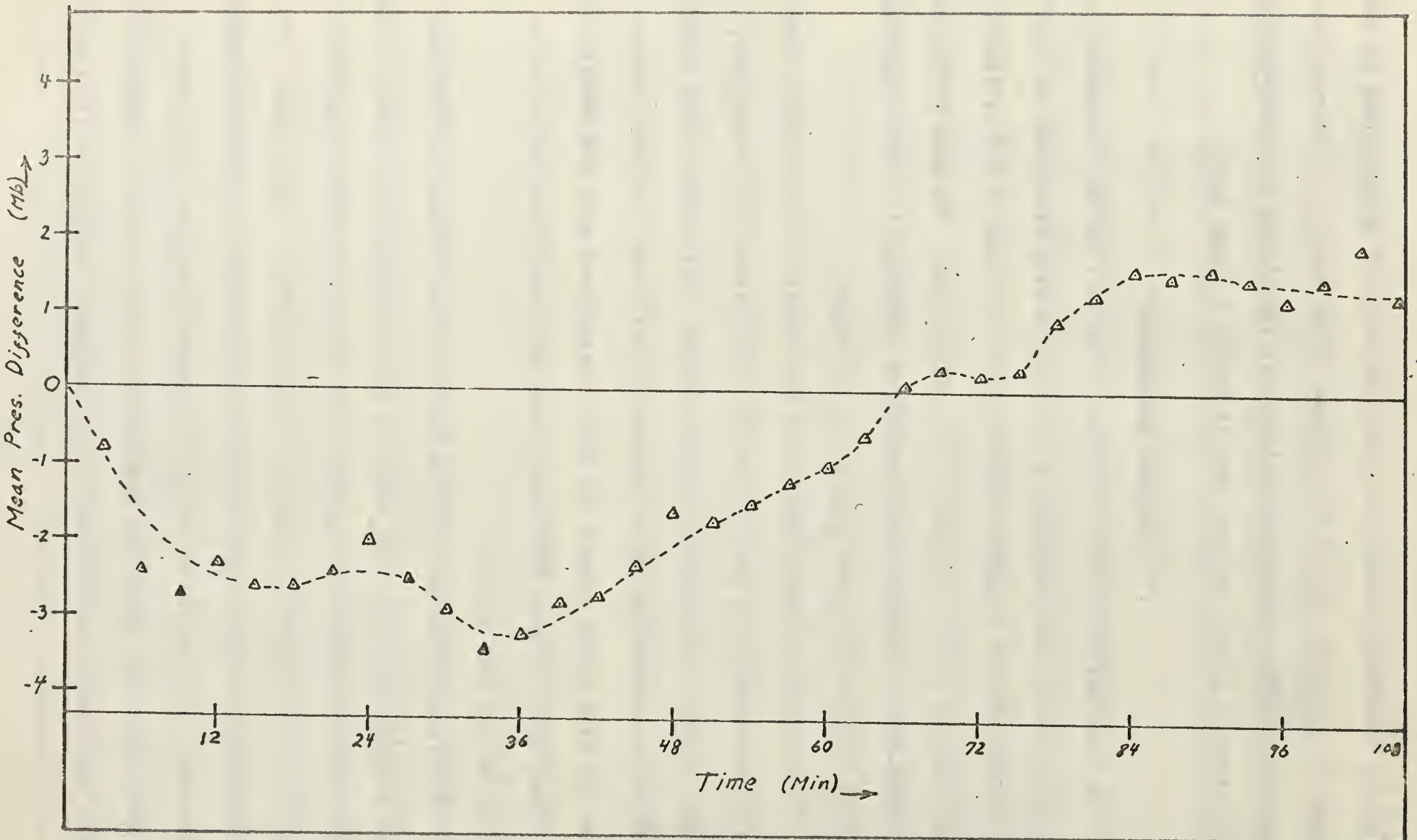


Figure 2. Mean Pressure Differences at Three-Minute Intervals.

the baroswitch compartment of the AMT-11 was only a few degrees warmer than the ambient temperature whereas the baroswitch compartment of the AMT-4B stabilized at OC in a circulating environment at a temperature of -28C. In the same experiments, while the pressure indications of both instruments varied with temperature changes, the AMT-4B experienced the greater variations, indicating a pressure increase as the temperature decreased. This phenomenon could account for the sign change in the mean difference values between the 63rd and 66th minute and a gradual approach to a quasi-constant difference.

Sounding number 37 resulted in the greatest pressure difference in the included sample with a maximum of 17.0 millibars having occurred at the 30th minute, with the AMT-11 having the greater pressure. In view of such gross differences, the initial commutator contact setting immediately becomes suspect of error. However, at the 72nd minute the difference was zero and from thence onward the AMT-4B recorded the greater pressure values. The difference reached a quasi-constant value of 1.5 mb at the 78th minute and the comparison terminated at the 105th minute in a 2.0-mb difference.

A certain degree of subjectivity is unavoidable in the linear interpolation of contact count and in evaluating the contact from the pressure calibration chart. Therefore, differences of 0.5 millibars can be considered insignificant. Differences greater than 0.5 millibars, however, can safely be attributed to a basic disagreement between the baroswitches.

TEMPERATURE DIFFERENCES

Differences were obtained by subtracting the AMT-11 temperatures

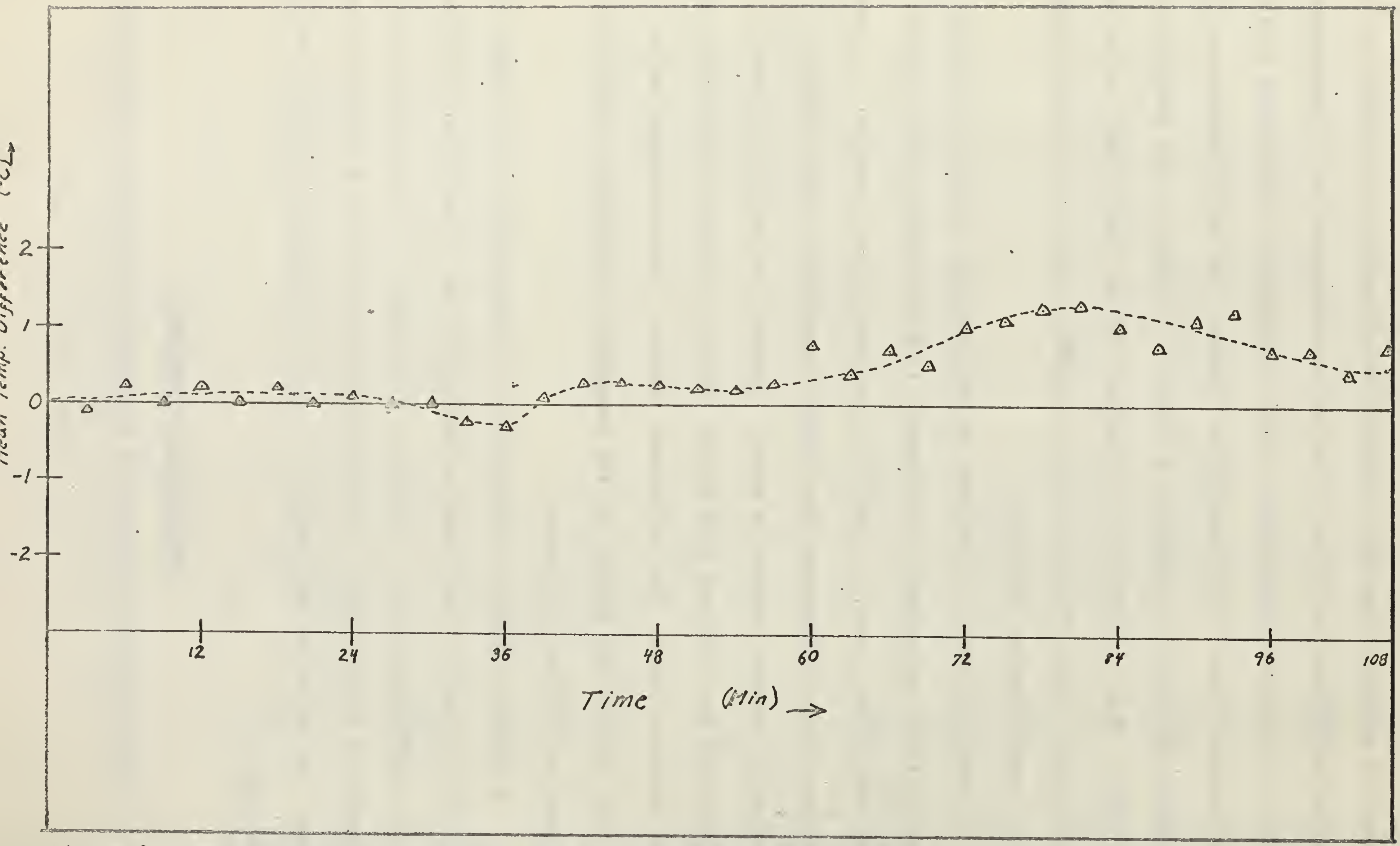


Figure 3. Mean Temperature Differences at Three-Minute Intervals.

from the corresponding AMT-4B values. While a few soundings experienced differences greater than 5.0C, the majority had a maximum difference of less than 3.0C.

The mean value of all observed temperature differences is 0.6C and the standard deviation from this mean is 0.9C. Both values are relatively small but not truly representative since the maximum differences of minimum recorded temperature occurred in those soundings which were omitted. The values do, however, depict the normal differences to be expected from the two sensing elements.

Figure 3 consists of a plot of the mean temperature differences as a function of time. The differences maintain an even distribution about the zero axis until the 39th minute where they become positive and remain so thence onward. A maximum value occurs between the 78th and 81st minute which was the nominal time interval during which the level of minimum temperature was traversed.

Comparison of Figure 3 with the differences obtained at constant pressure surfaces shown in Tables VI and VII renders the temperature elements slightly more credible when differences are determined at fixed time intervals. However, the AMT-4B sensing element has lost none of its bias toward warmer temperatures at high altitude in the latter comparison and remains suspect of error in a low temperature regime.

RELATIVE HUMIDITY

The lithium-chloride and carbon sensing elements are hopelessly incompatible and no new insight concerning their performance was gained through the time comparison. Subtraction of the AMT-11 humidities from the AMT-4B corresponding values resulted in positive mean differences at all time-intervals, with the mean differences being of the same order

of magnitude as those in Tables VIII and IX. Further, the majority of the soundings used in the time comparison experienced motorboating by the AMT-11 above 1.5 km and the bulk of the obtained differences served only to compare the motorboating signal of the lithium-chloride element to the humidity trace of the carbon element.

While little conceivable gain could be achieved by further instrument expenditures, a good time comparison of humidity element response could be conducted in a moist regime by the same techniques described herein, if such a comparison is desired. Of most interest would be the response of the individual elements to a moisture content which changes rapidly in the vertical and this could be at least partially accomplished by comparing the humidity records of soundings 36 through 51 at, say, 20-second intervals. Humidity changes in the vertical often take place quite rapidly and for any study of the sensing element response to be of value, comparisons would have to be made at intervals spaced closely enough to include all of the variations.

8. An Evaluation of Humidity Elements.

The accuracy of humidity data determined by radiosonde leaves much to be desired. Under the ideal conditions of the lower troposphere the elements differed with a nominal standard deviation of eight percent with difference values ranging well beyond that. (See Tables VIII and IX). Bearing in mind that the sensing elements used are of entirely different operating characteristics, the fact remains that these elements are an integral component in currently-used radiosonde equipment and the determined difference can certainly be considered excessive, if not actually gross.

A qualitative analysis indicates that the ML-476 carbon element records values which are too high when the humidity is low and the ML-379/AM lithium-chloride element indicates values which are too low when the humidity is high. The latter discrepancy has already been attested to by the failure of the ML-379/AM element to indicate saturation. The carbon element has made itself suspect in the low humidity regimes because it persisted in recording values up to 30 percent while the lithium-chloride element transmitted a motorboating signal. Ascents through dry layers were in most cases uneventful, but on occasion the AMT-11 signal exceeded the motorboating value of 5.0 ordinate while the AMT-4B signal remained steady somewhere between 83 and 85 ordinates. In those cases where the AMT-11 signal briefly reached a nominal value of ten ordinates (29% at 10C) the AMT-4B indicated no perceptable change in its recorded value (See Plate X, Appendix I).

At a temperature of -20C and with a humidity of 26 percent, a six percent humidity change is required to effect a one-ordinate change in the recorded ordinate value of the AMT-4B. In a similar environment a

six ordinate change is realized from the AMT-11 signal, indicating that it has the better response when the atmosphere is relatively, but not completely dry.

The lithium-chloride element has an adverse feature in that it does not permit evaluation of the atmospheric moisture content when the temperature falls below -40C. There is nothing magic about a -40C temperature and water vapor does not disappear when the temperature drops below that value. In 15 of the 35 winter and spring soundings a good relative humidity trace had to be abandoned because the temperature dropped below -40C.

In sounding number 17 the humidity trace was evaluated above the -40C isotherm by evaluating the recorded ordinate values at the -40C isotherm. Correlation with the useable AMT-4B humidity record was so poor that the procedure was immediately abandoned. No attempt was made to extrapolate the relative humidity isolines beyond the -40C isotherm, but better correlation would have been attained had this been done.

From the above discussion, one important fact is exhibited; namely, the depth or extent of the moist layers is not currently reported by radiosonde stations utilizing lithium-chloride humidity sensing elements. With the present element calibration the values cannot be accurately evaluated, but with no change to the radiosonde code, humidity ordinate values could be reported in lieu of humidity when the signal is not in the motorboating mode but above the -40C isotherm. The reported ordinate values would then lend themselves to a subjective and qualitative analysis and the extent of appreciable moisture would be a definable parameter.

The foregoing proposal, if practiced, would be only a temporary stop-gap since an entirely different sensing element, whose sensitivity and accuracy will not be affected by the very parameter it is measuring, must be developed. The fact that present-day sensing elements do not measure the atmosphere's water vapor content to a desirable degree of accuracy is an objectionable feature of the radiosonde instrumentation, and it will remain a feature until an improved sensing element is developed.

9. An Evaluation of Temperature Elements.

From an analysis of the data of Tables IV, V, and VI, the obvious conclusion is drawn that the temperature elements disagreed, at times quite markedly, in their respective temperature indications. The basic concept of measuring atmospheric temperatures with a ceramic resistor seems to be sound and, with adequate refinement of the sensing elements, can result in accurate temperature measurement.

Careful examination of the sensing elements used revealed that the cross-sectional area, hence the mass, of the ML-405A/AM used with the AMT-11 transmitters is approximately three times that of the ML-419. As noted previously, the minimum temperature of sounding number 51 was reached at the 101st minute by the AMT-4B whereas the AMT-11C recorded its minimum temperature at 101 minutes plus 24 seconds and then recorded an isothermal layer five millibars (approximately 350 meters) thick. This was a relatively common phenomenon and little significance had been attached to its occurrence. However, in view of the associated mass differences, it is not unreasonable to assume that the smaller ML 419 element is the more sensitive of the two. Care must be taken to insure that sensitivity is not construed to mean accuracy, because which is the more accurate element is a somewhat disguised issue.

A plausible assumption can be made that the ML-405A/AM, though of larger mass and perhaps less sensitive, is more accurate in the norm, where the norm is defined as a standard temperature lapse rate of 6C per kilometers. Situations outside the norm were those in which sharp inversions resulted in the negative lapse rates of 40C per kilometer, and in these situations the lag error of both elements was undoubtedly

exaggerated with the larger mass resulting in a slower response. In the mean temperature lapse of the troposphere a time lag constant of ten seconds results in a 0.3C temperature lag if ascent is at 300 meters per minute. With the same ascension rate through a sharp inversion the lag becomes amplified to 2.0C, a value outside the realm of acceptability.

The design problem is then to produce a ceramic resistor whose resistance variability with temperature is sufficiently measurable to indicate true temperature values over the entire range of temperatures experienced in an atmospheric sounding but sufficiently small to have a time lag of 3 seconds or less.

Both elements were exposed to the same degree of solar radiation and while absorption differences could have existed, insolation is not thought to have influenced the AMT-4B's reluctance to indicate very cold temperatures. The reluctance is more likely due to poor response in the low temperature range and the relatively high equipment temperature caused by the internally mounted battery. Both of these latter discrepancies can be corrected through better quality control of the temperature elements and minor alterations to the temperature element mounting configuration. External mounting of the battery is not proposed for reasons to be discussed in Section 10.

Solar radiation is presumed to have had an equal effect on both temperature sensing elements and no attempt was made to apply radiation corrections to observed values. The standard radiation correction values, available graphically, are a cancelled section (for the Navy) of the Manual of Radiosonde Observations and are currently in need of reevaluation. Research conducted in the general procedure proposed in Section 5 could accomplish achievement of reliable radiation correction

factors at not too great an expense.

Soundings would have to be taken at approximately three-hour intervals, commencing before dawn and terminating after nightfall, at fixed latitude intervals and at fixed intervals throughout one year. The before-dawn and after-nightfall soundings would serve as anchor points for a linear temperature change line for a given day and data observed at the respective altitude would fall either above or below the assumed linear diurnal change. Assuming five-degree latitude intervals, three consecutive days per time interval, and ten day intervals, the entire goal could be achieved with the expenditure of 12,000 instruments in the entire hemisphere or 648 flights by each research station. This represents an excess of 532 instruments over the amount currently expended in operational soundings by a single station and is admittedly an ambitious undertaking whose feasibility depends upon the degree of accuracy required from present-day equipment.

10. An Evaluation of Baroswitches.

The baroswitches used in all instruments tested were essentially the same and their performance may be most simply described as poor.

In an attempt to determine the thermal effects of the internally mounted battery Andersen[6] showed that at constant pressure but variable temperature baroswitches do not indicate exactly the same pressure reading. Therefore, the thermo-mechanical compensations used to suppress the effects of temperature change are inadequate.

The lag of aneroid cells is usually small and presumably can be corrected in calibration. Particularly at lower levels where pressure changes rapidly with height the aneroid should have very little if any lag error. At higher altitudes and colder temperatures the lag is more appreciable.

In constructing the minute-by-minute plot of the temperature curve for the AMT-11 transmitters many spurious superadiabatic lapse rates occurred between the 400-mb level and the tropopause. These superadiabatic lapse rates could not be verified by the AMT-4B temperature records and since they occurred over one- or two-minute intervals they have been termed "spurious". The overall lapse rates in this layer were very nearly dry adiabatic so a small discrepancy in reported pressure would decrease the reported pressure thickness between minutes with an attendent apparent increase in lapse rate.

Further evidence of baroswitch lag is obtained from the minute-by-minute pressure values themselves. In sounding number 11 a pressure change of ten millibars per minute near the 200-mb level slowed to eight millibars per minute from 191 to 183 mb. The baroswitch then changed ten mb in the next minute, then six and again eight. Over this same interval

the accompanying AMT-4B millibar change per minute ranged from fifteen down to six, but not at a steady rate of change.

Ascension rates vary throughout the atmosphere but not to the extent required for accelerations indicated by the preceding rates of pressure change. In the case of the AMT-11DX an acceleration of 80 m/min^2 would have been required to lend credence to the values indicated by the baroswitch. This value by itself is not especially large, but in the same interval the AMT-4B indicated slight deceleration.

Sounding number 11 was selected for discussion purely at random. Similar phenomona were observed in all soundings at temperatures below -50C and above 300 mb.

Witt[9] placed various radiosondes in a vacuum chamber to determine whether or not the baroswitches would return to their starting points if a simulated ascent was made and then pressure returned to its ambient value. Each simulated flight was accompanied either by a precision aneroid or a manometer and while the object of his research was not a calibration check on the instruments, Witt did detect a difference of eight millibars at 500 millibars pressure in one instance with an AMT-4B transmitter. The upper limit of his simulated flights was set by the vacuum pump and no error values are available at pressures lower than 275 mb. Maximum accuracy of the baroswitches tested occurred at 730 mb and accuracy decreased slowly above and below that level. No coolant was introduced in the chamber so ascent through the atmosphere was not simulated thermally.

Latimer[8], in a comparison of radiosonde data obtained from different nations, states, "In discussing the accuracy of height data computed from upper air soundings, it is necessary to distinguish between the heights computed for constant pressure surfaces and heights

assigned to specific points-----".[6] Both heights are computed in the same manner, but as Latimer showed, the accuracies of the heights are quite different, with the standard deviation of errors in computing the height of an inversion, say, over twice the standard deviation of errors in computing the height of a pressure surface. Therefore, the height of a given pressure surface can be determined more accurately than the height of the transmitter at the time it indicated this pressure. From Latimer's values the user can then expect that while the reported 500-mb height has

TABLE XV

Standard Deviation of Altitude Errors for Constant Pressure Surfaces and Specific Points in the Atmosphere Assuming (1) 1C Temperature Error, (2) 3mb pressure error through 200 mb, 2 mb error at 100mb, and 1.5 mb error at 50 mb[a]

Pressure (mb)	Pressure Altitude Error (m)	Altitude Error (m)
700	10	25
500	20	48
300	36	76
200	49	108
100	70	145
50	89	210

[a]After Latimer

a 68 percent chance of being within 20 meters of the true value, the height of a reported inversion near the 500-mb level may vary within the same confidence limits up to 48 meters. This doubling of possible error is due solely to erroneous pressure measurement by the baroswitch, whose

[6]J. R. Latimer, "Radiosonde Intercomparison" (Unpublished Master's thesis, The University of Toronto, 1959) p. 17.

error becomes of major importance in determining the true height of the transmitter at the time it indicates a given pressure. When wind velocity values are assigned to standard height reporting levels their accuracy is impaired also by erroneous pressure measurement. Subjected to the same error are the height of the freezing level and the height of the tropopause, both important meteorological parameters.

CALIBRATION CHARTS

The pressure calibration charts provided by the manufacturers have 50 percent of the sounding compressed into 10 percent of the chart. This constitutes a very real source of error in linear interpolation between contact values, especially since the upper 50 percent is that which is compressed, where a small pressure indication error makes the largest difference. Near the 10-mb level a pressure error of 0.5 millibars results in an instrument altitude error of 335 meters and 0.5 millibars is extremely difficult to resolve on the calibration charts provided. An expanded scale should be provided from the 105th contact to the upper end of calibration.

SEGMENTED SIGNALS

In sounding number 15 the AMT-11DX recorded its maximum relative humidity for the sounding (81%) while the AMT-4B was engaged in transmission of a low reference which resulted in its maximum falling at a different level with a value of 73 percent. Evaluation of the observed AMT-4B humidity "trend" resulted in a value of 71 percent for the same time at which the AMT-11DX recorded 81 percent. The magnitude of this difference can be more fully appreciated with reference to Tables II and III which indicate that in the majority of the observations the

AMT-4B humidity maximum exceeded that of the AMT-11.

In sounding number 48 the AMT-11C humidity record indicated a trend toward a relative maximum point but the humidity trace was pre-empted by the low reference signal. At the same time the AMT-4B transmitted a clearly defined relative minimum.

This latter is an isolated example but the former was evidenced in one or the other of the records in nearly all of the soundings. No specific study has been made to evaluate the resultant differences since the elements involved are not compatible in the steady state.

The temperature trace , of course, is lost also during transmission of both reference and humidity but at least it is a part of every contact and amenable to simple triangulation. In some examples, however, a slight inversion noted by one instrument went undetected by the other, apparently because of the interrupted temperature record, and often times the maxima and minima had to be determined by triangulation. Again no specific study of resultant differences was conducted because the sensing elements involved do not agree in the steady state.

With the exception of sharp inversions the humidity trace suffers more than the temperature from the segmenting of the record. This condition can be corrected at no small expense by completely redesigning the transmitters and the receiver/recorder units. Humidity could be made a continuous signal at one frequency recorded by a separate pen arm on an expanded recorder chart with time-sharing of a common signal at a slightly different frequency by temperature and pressure reference.

The baroswitch as a pressure sensing device is inadequate at high altitudes and not really outstanding at low levels. A hypsometer which determines pressures from the boiling point of carbon disulfide is

already in use at a select few radiosonde stations and measures pressure very accurately. It shows a roughly logarithmic variation of vapor pressure with height and for a given temperature error in the boiling-point measurement, there is a nearly constant error in calculated height. Further, its accuracy increases as pressure decreases. In the balloon-soundable atmosphere, its pressure measurements have a precision of 0.1 millibars or, put another way, its calculated height at 30km is within 72 meters of being true. At this same altitude baroswitches tested commonly disagreed by two millibars which resulted in a plus or minus altitude factor of around 1,500 meters. This latter figure introduces substantial error in assigning wind velocity values to the 10-mb level.

The baroswitch with its aneroid cell is insufficiently accurate to sound the atmosphere with the present-day precision required.

11. Instrument Performance and Related Subjects.

The AMT-4B transmitter with an amplitude-modulated signal at 1680 mcs generally outperformed the AMT-11 transmitter which used a pulse-modulated signal at 403mcs. Outperformed can be construed to mean the signal quality was much better with very little reference drift and fewer AMT-4B soundings terminated at low levels due to signal failure.

FREQUENCY CONSIDERATIONS

Of the 48 AMT-11 flights which passed through the tropopause, 39 experienced a deteriorating signal at and/or above the tropopause. In some cases the deterioration was very pronounced while others changed from a very good signal to a very poor one over a substantial altitude and time interval, suggesting that some of the poor quality had been caused by a weakened power supply. Signal deterioration above the tropopause is a phenomenon experienced by all radiosonde operators who use the AMT-11 transmitters and seems best explainable by the frequency at which the signal is transmitted rather than by signal strength.

Considering the inherent temperature gradient difference above and below the tropopause, it may be likened to the thermocline near the ocean surface which passes higher frequency sound waves with less diffraction than is realized from transmission of low frequency sound.

The equipment configuration included a 30-degree directional receiver antenna for the 403mc signal which was trained on the transmitter at all times by the AMT-4B tracking antenna. Signal reception conditions could not have been more ideal for the SMQ-1A receiver, yet the quality of the signal was usually poor, especially above the tropopause. A positive correlation between the elevation angle of the transmitter at

and above the tropopause and the quality of the signal was obtained by reference to the GMD-1 recorded angles at the time of tropopause penetration. Little doubt remains that the angle of penetration has a definite effect on the 403-mc signal, with lower angles producing poorer signal reception. Those soundings which did not experience a deteriorating AMT-11 signal after tropopause penetration had elevation angles greater than 20 degrees at and above the tropopause and the most marked signal deterioration took place when angles were less than ten degrees.

The range can certainly be considered a factor in signal deterioration also, since low elevation angles were the direct result of strong winds which carried the transmitter a greater horizontal distance. But the very fact that the deterioration always took place at and above the tropopause and that the GMD-1 equipment enjoyed near-perfect reception at all levels strongly suggests that the frequency of the signal and not only its strength determines the reception quality attainable.

REFERENCE DRIFT

The SMQ-1A receiver/recorder unit almost constantly required reference drift correction with an attendant drift correction to the recorded temperature and humidity values. The TMQ-5 recorder used in conjunction with the AMT-4B transmitters required no drift corrections in most cases.

In addition to the inconvenience imposed on the operator and the extra time required for evaluating the drift corrections, the accuracy of the recorded values becomes suspect of error. The temperature differences obtained from two of the four AMT-11DX soundings where gross or excessive reference drift occurred fall outside the respective standard deviations of the mean differences obtained from all soundings.

Sounding number one, which terminated due to excessive reference drift on the part of the AMT-11DX, is unique in that the AMT-11DX temperatures in a 3-km layer above the level of minimum temperature, are warmer than the respective AMT-4B temperatures. A standard drift correction nomogram was used for all corrections but obviously this resulted in some insufficient corrections in the case of sounding number one.

Inference is not intended that a sounding should be terminated as soon as reference drift occurs, but more realism would exist if data were classified as "doubtful" whenever excessive reference drift corrections are necessary.

FREQUENCY SHIFTS

Several AMT-11 transmitters, for reasons still unknown, experienced a constant frequency shift in changing from temperature to humidity transmission. On a few occasions, temperature, humidity, and reference values all had their own individual transmitting frequencies, usually about 0.3 mc apart. This phenomena did not influence the quality of the signal as a whole and is included mainly because of the annoyance factor involved which could very well influence the disposition of an operator on a pitching and rolling ship. (AMT-11 transmitters are used mainly aboard ships).

The AMT-4B signal is monitored by an automatic frequency control unit (AFC) and if any frequency shifts occurred, they certainly presented no problem to the operator. The AMT-11 frequency shifts, however, could very easily influence abandonment of a static-filled but still useable signal and, if economically possible, should be corrected immediately.

EVALUATION OF POOR TEMPERATURE TRACE

Radiosonde operators the world over, in efforts to obtain the maximum amount of information from a given flight, make visual checks on the recorder pen position, and when the signal begins to fade mark the flight record at the pen's position when a clear signal is detected audibly. Data obtained in this fashion is, at best, regarded as doubtful and is most often not evaluated.

This practice was engaged in during the test flights compiled herein and an evaluation of the "doubtful" data revealed that it is no more doubtful than any other data. Care was exercised to mark the records (generally the AMT-11) at the precise location of the recording pen during a usually very brief, but steady, temperature tone. Linear interpolation was used between marks and contact count was easily made on the pressure references. Admittedly, some degree of experience and skill is required on the part of the operator, but universal practice of this procedure would most certainly result in more meteorological data at high altitudes. Data obtained in this manner could, and should, be classified as doubtful, but even doubtful data are better than no data at all.

THERMAL EFFECTS OF THE BATTERY MOUNTING

The AMT-4B transmitter was chosen for discussion here because its features of construction seem to have played the biggest role in its performance.

In one of his experiments to determine the effects of battery temperature Anderson[6] placed a thermocouple near the baroswitch of an AMT-4B transmitter, another in the battery compartment and third five centimeters from the temperature sensing element. All thermocouple

temperatures were recorded on a remote temperature indicator/recorder unit.

With an ambient temperature of -28C the baroswitch compartment remained at OC while the battery compartment reached 55C. The radiosonde temperature indicated by the recorded trace and the thermocouple temperature were within 0.5 degrees of each other at all times. If a systematic error existed in either instrument it was not detectable by the equipment used. At an ambient temperature of 16C the battery compartment reached 80C and baroswitch thermocouple indicated 40C.

The baroswitch itself, upon being placed in the freezing compartment decreased 2.5 millibars from its initial setting and after 27 minutes indicated a pressure one millibar greater than its initial setting. Removal from the freezer resulted in a further pressure increase of two millibars and then a gradual return to the initial setting. Ambient pressure variation was neglected throughout the experiment since the time span was slightly more than one hour. Andersen's complete report was not available at the time of this writing but should contain interesting revelations on the behavior of instruments when they are subjected to varying thermal conditions.

The internally mounted battery resulted in one apparent advantage in that it kept the baroswitch compartment relatively warm. This could very well have been the sole cause for the AMT-4B having failed to indicate spurious superadiabatic lapse rates since much of the aneroid lag is removed by heat.

Unfortunately, its power supply kept the whole modulator assembly warm and from the results of sounding number 51, could very well have been a prime factor in its relatively warm temperature measurements.

No effort was put forth to determine what effect the battery heat might have on the humidity sensing element, which is more in proximity with the heat source than is the temperature element. The resistance of the element decreases, however, as temperature increases, and an extraneous heat source would have resulted in an apparent decrease in humidity.

The humidity evaluation of Section 6 showed the AMT-4B to indicate the higher humidity values, normally, so a reasonably safe assumption can be made that the humidity element is affected very little by the battery heat and any deviations from the true value are within the normal range of accuracy available from the carbon sensing element. Further, a temperature change of approximately ten degrees is required to effect a one percent change in humidity and the thermal effect of the battery could hardly have exceeded this value.

HUMIDITY GROUND CALIBRATION

Ground calibration (baseline check) of the humidity element requires that two consecutive humidity values be recorded in vertical alignment, in other words, identical values, for realization of a successful baseline check. The carbon element of the AMT-4B stabilized at about the same time as the temperature record, presenting no problem whatever. The lithium-chloride element, however, continued to drift for tens of minutes, eventually approaching a vertical asymptote very slowly.

The problem presented is that excessive time was spent with a power drain on the battery, and a subsequent excessive time lead was required to meet launch schedule. More important is the fact that operators were observed to utilize a "wide pencil" in connecting the humidity traces to simulate vertical alignment and one experienced individual was observed

to force vertical alignment through skillful manipulation of the SMQ-1A reference-adjust control. Obviously, if the baseline requirement is dealt with in such fashion, no good can come of it.

More realism was achieved by acceptance of a three-contact humidity trend. An acceptable trend was considered one in which the three contacts could be connected by a straight line and baseline psychrometric data were taken at the precise instant at which the third humidity contact terminated. This procedure was used for 15 flights and the maximum difference between the recorded value and the psychrometric value was three percent. This value occurred only once, and a two percent difference occurred twice. The remainder resulted in a zero or one percent difference.

With no loss of accuracy and a substantial reduction in time spent in ground calibration, the obvious conclusion is that acceptance of a trend from the lithium-chloride element is more realistic than is the more stringent requirement for vertical alignment. Paragraph 2320(2)(b) in the Manual of Radiosonde Observations[3] should be changed to reflect this less stringent requirement with the included cautions that the recorded humidity values do fall on a straight line, that the temperature trace is vertically aligned to insure stability of the baseline check box, and that the psychrometric readings are obtained at the precise instant at which the third humidity value of the trend terminates.

This procedure, if followed, will result in less ground check battery drain and a subsequent greater airborne battery life. Further, it will provide a check on the lithium-chloride element which is at least as accurate as that realized from existing requirements with less required lead time.

12. Heat Spikes.

Reynolds and Lamberth[5] in conducting constant-level balloon flights at the White Sands Missile Range, observed a phenomenon which they termed, "heat spikes", and which they atrributed to heat from the boundary layer surrounding a balloon train. Their flight equipment consisted of AMT-4B and AMT-15 radiosondes, the latter differing mainly from the former in that it employs a clock-mechanism for switching the various parameters in and out of the circuit. The extraneous heat spikes were successfully suppressed through downward vertical displacement of the temperature sensing element.

Figures 4 and 5 are reproductions of the AMT-4B flight records of soundings number seven and 42,respectively. Sounding number seven very nearly approximates a constant-level balloon whereas number 42 is an illustration of a slowly ascending balloon. The recorder scale has been compressed laterally to include reference values.

The temperature record obtained from number seven has many sinusoidal oscillations superimposed on the over-all trace with less pronounced maximum points to reflect the heat spikes. The temperature trace from 146.0 to 145.4 contacts was a nearly pure sine wave with fewer relative maxima and in the following trace (not shown) the oscillations diminished to very small values. The AMT-11DX transmitter had ceased to function when this phenomena was recorded.

Sounding number 42 exhibited greater magnitude deviations from an ascending balloon (see Figure 5). The accompanying AMT-11C transmitter was functioning perfectly at this time and failed to indicate a similar phenomenon. Among others in which the AMT-4B recorded heat spikes, sounding number five was the only example in which the AMT-11 transmitter

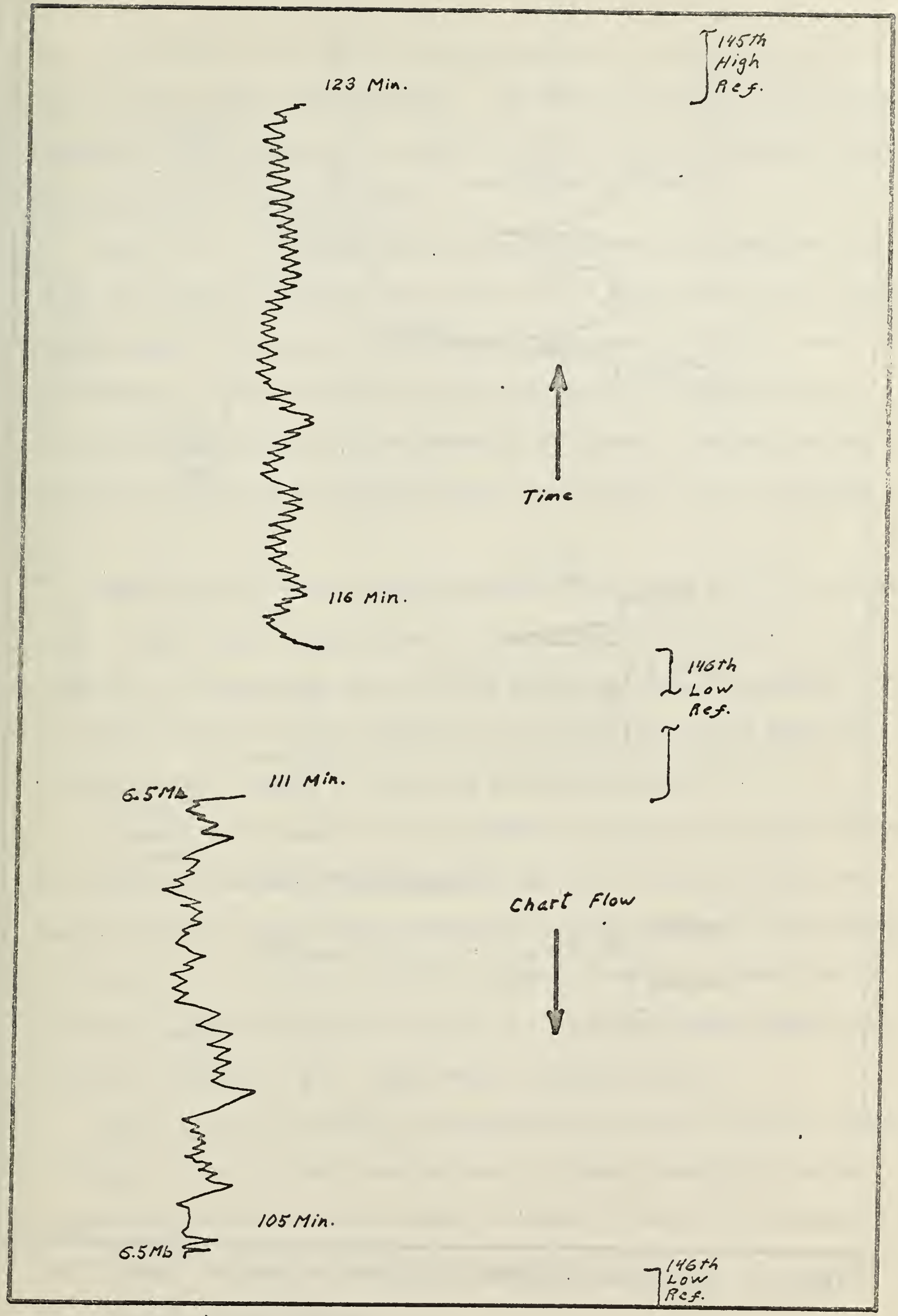


Figure 4. Heat Spikes Observed During Slow Descent.

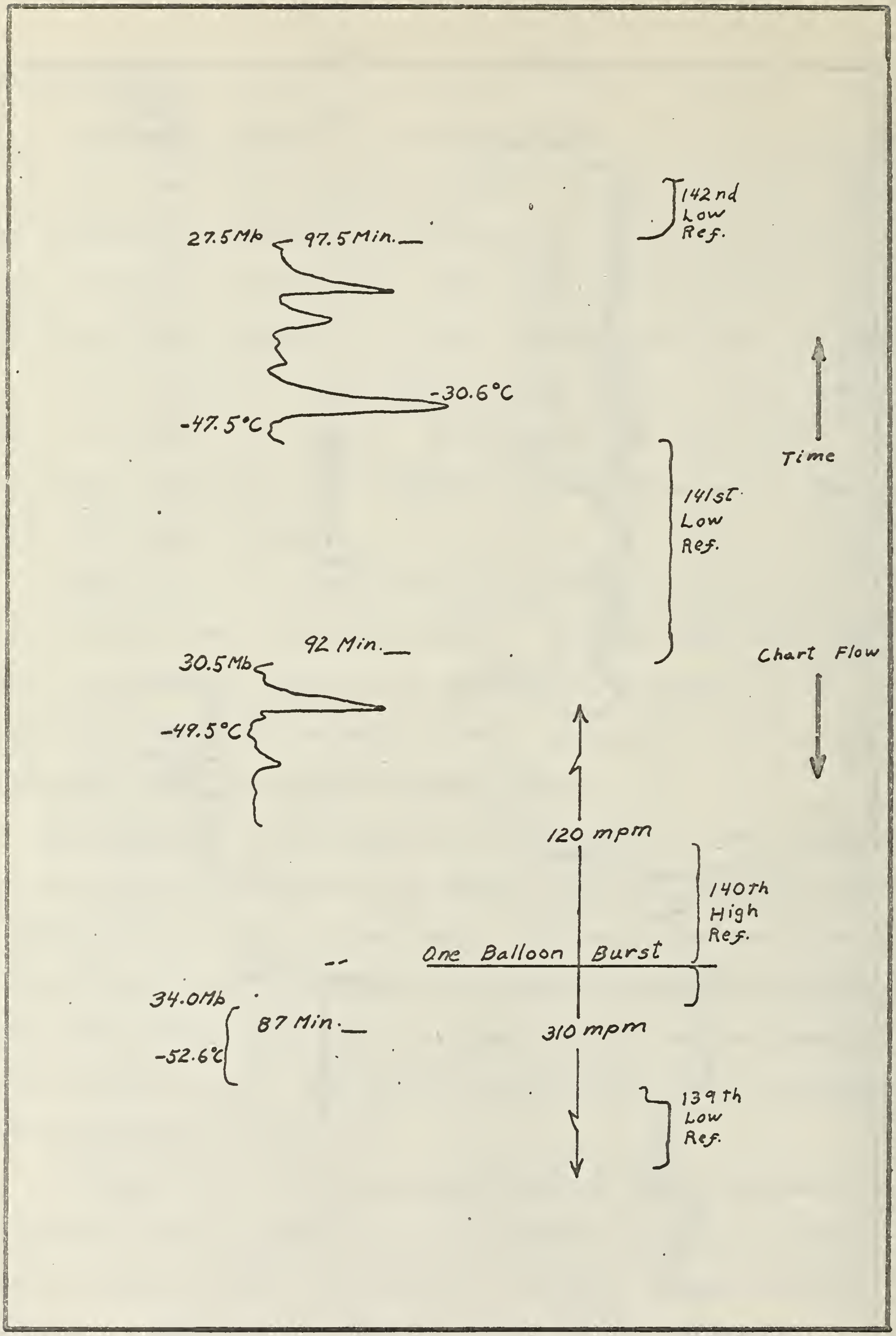


Figure 5. Heat Spikes Observed During Slow Ascent.

was functioning at the time they were recorded. It, too, did not result in heat spikes from the AMT-11. In short, the AMT-11 transmitter never did record heat spikes, which makes the internally mounted battery a prime suspect for their cause.

Ney, et. al.[4] showed from a carefully conducted study that heat from the equipment boundary layer flows upward during the day and their results seems borne out by the phenomena witnessed in flights seven and 42. Sounding number seven, which was descending very slowly, had the less pronounced spikes whereas number 42 continued to ascend, thereby placing the temperature sensing element in the warmer, also ascending air.

Soundings five and six exhibited heat spikes with both balloons present. Since visual observations at 28km showed the balloons to be well separated, an assumption can be safely made that the gas temperature in the balloon had no effect whatever on the production of the heat spikes. That the battery played a major role is unquestionable.

Little doubt remains that the spikes are caused by a thermal boundary condition but one could argue that the AMT-11 did not record heat spikes because of lag in the temperature sensing element. This argument is belied by the fact that, while the AMT-11 element may have more lag, its lag is not sufficient to preclude its indicating some response to a boundary influence, had a large enough boundary existed.

The time rate of change of temperature indicated by the heat spikes of Figure 5 is no greater than the rate of change experienced during penetration of the inversions shown in Plates I through XV, Appendix I. The boundary surrounding the AMT-11 transmitter is simply not as warm as the boundary of the AMT-4B.

The heat spikes of the AMT-4B transmitter, coupled with its consistent failure to indicate as cold a temperature as the accompanying AMT-11 transmitters, raise serious doubt concerning the temperature element's mounting position. Heat spikes present no problem in the average balloon sounding but the lack of response to cold temperatures is an existent condition that may be partially corrected by relocation of the thermistor.

The configuration used by Reynolds and Lamberth solves the problem nicely but constitutes an assembly which could easily result in breaking of the temperature element during launching procedures, especially in a strong wind. The same results could be achieved by lengthening the element supporting arms to about three times their present length thus positioning the thermistor more remote from the heat source. External mounting of the battery is not proposed because, as discussed in Section 11, the internal configuration serves to keep the baroswitch at a relatively warm temperature and apparently more responsive to pressure changes.

13. Reduction of Radiosonde Data by Electronic Computer.

Computerization of radiosonde data reduction achieved substantial improvement in the two very important realms of accuracy and speed. This achievement was realized in many other aspects of the meteorological science a decade ago but radiosonde data are not reduced by electronic computer on a wide-scale operational basis as yet.

ACCURACY CONSIDERATIONS

The human element must be included in any discussion of errors in which that element can play a role. Latimer[8] determined the personal error of an experienced operator in computing a thickness between two levels of pressure P_1 and P_2 to have a mean value of ten meters and a standard deviation of 17 meters. The mean error is an absolute value and the thickness of the levels over which it was obtained was not specified. Actually, the human error present in pressure-altitude computations should have a mean value of near zero if a large enough sample is used because a positive ten-meter error should somewhere be cancelled by a negative ten-meter error. Exceptions would occur in determining an area average of the mean virtual temperature over a layer which contains a sharp inversion or otherwise variable lapse rate with no similar phenomena elsewhere in succeeding layers. In this instance, an error introduced by erroneous area averaging would remain uncancelled, affecting the pressure altitude values at every level above. Mean virtual temperature as used herein is given by: $Tv = (1 + 0.6078m)T$ where T is the actual temperature in degrees Kelvin and m is the mixing ratio in grams of water vapor per gram of dry air.

No method currently exists for a complete divorce from the human

element; however, some accuracy is gained in the final product by excluding as much of the human element as possible. Table XVI lists the differences at a few selected levels which resulted from a comparison of pressure-altitudes determined from the adiabatic charts with those determined by electronic computer. For ease in comparison the differences between two soundings for the same levels were taken from Table XIII and included also.

TABLE XVI

PRESSURE-ALTITUDE DIFFERENCES
BETWEEN
GRAPHICAL AND COMPUTER-PROCESSED DATA

Pressure (mb)	AMT-4B Mean (m)	AMT-4B Std. Dev (m)	AMT-11 Mean (m)	AMT-11 Std. Dev. (m)
700	-1.4 (1.3)	4.8 (7.7)	0.4	2.1
500	9.0 (4.7)	13.6 (16.1)	-2.5	13.4
200	2.9 (34.1)	23.1 (48.5)	-0.6	21.7
50	2.9 (106.2)	38.8 (101.7)	3.5	18.5

NOTE: Number in parentheses is the value arising from comparison of data between two radiosondes taken from Table XIII.

The Table XVI entries were derived by subtracting the computer-determined heights from the respective hand-calculated values, then computing mean values at the various levels. The hand drawn products were not subjected to inter-comparison. In an effort to achieve realistic values of personal error, all values which would have undoubtedly been coded and transmitted were left as is. The mean difference values are fairly small but the standard deviations suggest a wide range of differences. The 500-mb level in the AMT-4B computations reflects three gross errors, one of 58 meters.

Of real significance is the fact that all gross errors were traced

back to the human element and arose from errors in reading the temperature evaluator, area averaging, summation of thickness values, and in reading the thickness values from the adiabat. Incorrect point plotting was equally common. No breakdown on specific sources of error is included nor is one considered necessary. Some less experienced personnel computed graphical solutions and made fewer errors than did the more knowing individuals, probably because they worked under close supervision and were more careful.

Since all adiabatic records are checked at the National Weather Records Center, Ashville, N. C., the adiabatic solutions are usually checked quite scrupulously before the records are sent to NWRC. Many errors are uncovered in this manner but the very close check usually takes place after the radiosonde data has been coded and transmitted and does the user no good whatever. The attempt herein was to depict differences as they affect the coded message.

The errors which would have been uncovered in the checking prior to being sent to NWRC but not before transmission were removed and the mean difference values were recomputed with the results appearing in TABLE XVII. Again, the radiosonde intercomparison values are included.

As anticipated, the mean values are very near zero indicating that human frailties are unbiased, but the standard deviations imply correctly that the range of error is still substantial. Significance is attached to the fact that the differences between the human and machine products are less than the differences resulting from the inadequacies of the equipment.

Looked at in another light, this could suggest that the machine is almost as good as the human, but this approach was not taken herein because the computer was considered the more accurate of the two elements.

TABLE XVII

PRESSURE ALTITUDE DIFFERENCES BETWEEN GRAPHICAL
AND
COMPUTER PROCESSED DATA WITH GROSS ERRORS REMOVED

Pressure (mb)	AMT 4B Mean (m)	AMT-4B Std. Dev. (m)	AMT-11 Mean (m)	AMT-11 Std. Dev. (m)
700	-1.4 (1.3)	4.8 (7.7)	0.4	2.1
500	0.8 (4.7)	3.0 (16.1)	0.2	6.8
200	-0.1 (34.1)	5.5 (48.5)	-0.2	12.4
50	-1.5 (106.2)	13.6 (101.7)	2.4	11.7

NOTE: Values in parentheses are again repeated from Table XIII for ease in comparison. Gross errors were defined as those exceeding 10m at 700mb, 20m at 500mb, 30m at 200mb, and 50m at 50mb.

Reasons for this assumption are, (1) in the case of the AMT-4B, ordinate values are fed directly to the computer, eliminating the possibility of error in temperature or relative humidity evaluation, (2) data are read every minute, hence any error in recording either the pressure or ordinate values would be more easily detectable, and (3) if an error is made, the level concerned becomes one erroneous value among, say, 130 correct ones, thereby having a lesser effect on the overall product.

In a normal ascent, the data of which are reduced in the conventional manner, perhaps 30 significant levels will be constructed to represent the atmospheric profile. With as much as 50 millibars between levels, not only do the values of lapse rate and pressure change lose significance to the operator, but a one-degree temperature error goes a longer way.

From Tables XVI and XVII the errors introduced by manual temperature and humidity evaluation are apparent if the AMT-4B values are

compared to the AMT-11 corresponding values. The program for reduction of the latter requires the input of actual temperature and humidity so the computer works with precisely the same information as the graphical analyst. The differences are seen to be less, mainly, than those arising from the AMT-4B comparison.

Computer reduction of the latter includes machine computation of temperature and humidity through solution of the equations governing the behavior of the sensing elements as their resistance varies, and the pressure-altitude mean differences are seen to exceed those in which the computer has virtually the same information as the hand analyst. A careful check of the computer product revealed it to be the more accurate element in determining temperature and relative humidity values. This is not surprising since one ordinate division spans 1.5C on the high end of the temperature evaluator and 2.5C on the low end. In the same respective areas, a 0.1 difference in evaluator interpretation results in 0.15 and 0.25 degrees difference in recorded temperature.

Humans indicate a preference for certain 1/10 values and seemingly avoid deliberately the recording of others, so at any time the ordinate value is not on an even or half-value, bias is introduced into the interpolation. Of course this bias is not completely eliminated by machination because the recorder divisions are in units but must be read to the nearest one-tenth.

No specific study has been conducted to determine the differences arising from temperature-evaluator interpretation because a qualitative comparison revealed the differences to be generally less than 0.3C, a value which loses significance among the larger observed differences. Table XVII affords a comparison of the results of visual interpretation

of temperature if the assumption is made that the computer data are the more accurate. This assumption is quite sound since the computer is certainly unbiased and no systematic errors could be uncovered in its calculations.

SPEED CONSIDERATIONS

An electronic computer, when properly programmed, is extremely efficient and accurate in reducing radiosonde data. In essence, the computer performs successive solutions of the hydrostatic equation in the form of a "thickness" equation: $\Delta Z = \frac{R_d \overline{T}_v}{g} (\ln P_1/P_2)$.

Values for the equation parameters are:

ΔZ = thickness of the layer between P_1 and P_2 (meters)

R_d = gas constant for dry air (0.287 joules/gm °K)

g = gravitational force

$\overline{T}_v$ = mean virtual temperature of the layer (°K)

P_1/P_2 = ratio of the pressure at the bottom of the layer to that at the top

For the computer reductions included herein the data were coded for the computer at one-minute intervals with intermediate points selected between minutes when the temperature and/or relative humidity curve experienced an inflection point therein. On various occasions more than one intermediate level was required to accurately describe the respective records. From the temperature and humidity data ingested the computer determined a mean virtual temperature for the layer from P_1 and P_2 and used this information to compute a thickness value for the layer, which it added arithmetically to the previous altitude calculated. In effect, it "bootstrapped" itself through the soundings from the surface

to the termination points by successive solutions of the thickness equation.

That the solutions are made quite rapidly is attested to by the fact that 90 minutes were required to reduce 50 AMT-4B soundings and 70 minutes to reduce the same number of AMT-11 soundings. The latter required less time principally because wind values were not included and partially because the AMT-11 temperature and humidity ordinates are evaluated prior to computer ingestion.

Manual reduction required an average of 1.5 hours per flight record or 150 hours total and included the determination of temperature, humidity, and pressure-altitude values only. Computer reduction included the same information plus dewpoint, and wind (direction to the nearest whole degree, speed in m/sec and knots) at all standard levels, the same values plus pressure but less wind at all significant levels, and all of the foregoing plus mixing ratio, density, refractive index and the speed of sound at every 1000-foot increment. (see Appendix III). That this was accomplished on a computer with only an 8000-storage-cell capacity is truly amazing and certainly speaks well of the programmers' abilities.

Unfortunately, no complete documentation of either program was available at the time of this writing and none is included. Proper authorities will be able to procure any required program documentation or listing in the very near future as they become available. This should not be construed to mean that the programs themselves are not available for use, but only points out that until very recently both programs had been in a state of flux which resulted in general improvement and the latest changes were not reflected in the current listings. Not wishing to be misrepresented, Geophysics Division personnel at PMR

elected to withhold dissemination until the latest improvements are reflected.

Appendix II includes a partial reproduction of the PMR data encoding instructions. Instructions pertinent to AMT-11 data reduction have been omitted because they differ only in that actual values of temperature and humidity are encoded vice ordinate values and wind data are omitted.

In view of the circumstances, data cards for the Monterey soundings were cut at the U. S. Naval Postgraduate School and forwarded to Point Mugu for reduction.

The method currently employed at the Pacific Missile Range consists of data reception via radio or landline teletype which perforates a paper tape as it is received. The paper tape is then fed into an IBM tape-to-card converter which automatically punches the data cards which, in turn, are used directly for the CDC-3100 program data input.

The computer reduces the data and prints out the results in the form shown in Appendix III and simultaneously perforates an output tape which is used directly for transmission of the reduced data. To avoid excessive time on the teletype circuit, the data output at 1000-foot intervals is returned by mail to the radiosonde station and only the standard and significant levels are transmitted via teletype.

The Geophysics Division of the Pacific-Missile Range does not presently possess the equipment which could streamline the data processing, namely a method of receiving the raw data on magnetic tape for direct computer input. This would eliminate the time-consuming card handling and processing and reduced data could be disseminated by the same scheme.

Coding the data for IBM card perforation was easily accomplished as the ascents were being made. Even in those cases where the AMT-11 required drift corrections and the frequency constantly shifted as the various parameters were switched into the transmitting circuit, the entire sounding was coded ten to 15 minutes after its completion. The AMT-4B records were dealt with even more easily, because temperature and humidity ordinates required no evaluation.

Two persons on one receiver of either type could very easily have all the cards punched or a tape perforated for teletype transmission within 15 minutes after termination. Existing modus operundi requires three persons where wind data are computed and two where they are not. Evaluation of the entire sounding is completed one hour or more after its termination. Most stations presently transmit the message in two segments to avoid delay in getting the low level information disseminated. This procedure could be eliminated by computerized reduction because the entire sounding could be reduced and transmitted with fewer personnel involved and in the same time span as that presently required to produce the first transmitted segment.

Provided sufficient working capacity a computer could be programmed to encode the entire sounding in the existing code form, or the data could be transmitted in the printed form shown in Appendix III. This latter scheme would require more teletype time.

Since time and accuracy can both be enhanced by electronic computer reduction of radiosonde data, soundings should be reduced by computer in every possible instance. To equip all radiosonde stations with computers is not economically feasible, but obvious gains could be achieved in time and accuracy if reporting stations were to transmit their raw data to

centralized computer facilities for reduction and further transmission.

If followed, this procedure would initially result in a time loss with an accompanying dirth of errors. However, greater familiarity and experience would soon offset the initial slump and more precise and copious data would be available to the user.

14. Conclusions and Acknowledgements.

The differences in the various parameters at both fixed pressure levels and at fixed time intervals exceed the current tolerances given by the manufacturers. No one sensing element can be singled out as being worse than the others and, conversely, none is better. If accurate data are to be obtained by radiosonde flights the entire system must be considered inadequate and improvements must be initiated.

Due solely to signal reception considerations, 403mcs should be abandoned as a radiosonde frequency and all present receivers which are operative only in the 403mc range should be revamped or replaced.

The baroswitch reaches its limit of usefulness as a pressure sensing device in the troposphere and can be considered a major contributing factor in the present inadequacies of the radiosonde system. If accurate data are to be obtained at 30 to 40 kilometers a hypsometer must replace the baroswitch at about the 15-km level. Continuous transmission of relative humidity should be provided.

Ozone is an important atmospheric constituent which is not measured on an operational basis. However, it is concentrated mainly above 15 km where humidity becomes of little importance, and the design of future radiosondes would do well to include replacement of the humidity signal above 15 km by telemtry of an ozone signal.

The ceramic-resistor element as a temperature sensing device is adequately sensitive but must be made more accurate at low temperatures. When the accuracy is sufficiently improved, radiation correction factors can then be determined and the ultimate accuracy of balloon sounding temperatures will be realized.

A minor change must be made in temperature element location, also, and greater lateral displacement should be considered. Downward displacement will place the element in the warm wake of the ascending transmitter and is not recommended.

Neither of the humidity elements tested seems reliable. The carbon element indicates high when the humidity is low, and the lithium-chloride element indicates low when the humidity is high. If accurate humidity measurements are to be made, a different sensing element must be designed. The element, of necessity, must be one whose performance is not impaired in any way by the parameter which it is measuring.

Long-range weather forecasts will reach a reasonable degree of accuracy only when the variation of the parameters of the upper stratosphere are considered in the forecast. To be considered, the parameters must first be accurately determined, their behavior understood, and ultimately their behavior must be forecast. The present state of the art does not include accurate measurement, the basic ingredient upon which all else hinges. The current practice of smoothing high altitude data on the principle that one observation is as good as another reduces actual errors but only at the expense of the reliable observations, and an imperfect analysis cannot be consistently prognosticated into a perfect forecast.

For their assistance in obtaining data I am deeply indebted to August A. Bauer and Peter Vollmer, and especially to Robert A. MacBeth who not only provided the technical assistance required for the collection of accurate data, but reproduced in a professional manner the cross-sections of soundings 36 through 50 appearing in Appendix I. All aforementioned personnel gave freely of their off-duty hours to assist in the

flights. I am also indebted to Robert Landes who assisted in many of the flights and personally produced Figure 1, to my wife Barbara, who assisted in the coding of data for computer reduction and the proof-reading of some 9000 odd punched IBM cards and to Jeannette Van Vonderen who assisted in data coding. Included in the contributors to this thesis are E. M. Davies, AGCM, USN, and his assistants at the Geophysics Division, Pacific Missile Range, without whose help the computerized data reduction would have been impossible, and Virginia Ward who voluntarily rough-typed this entire manuscript, thereby freeing the author for additional research hours. My further thanks and deepest appreciation are extended to Professor Charles L. Taylor who not only afforded the opportunity for research in this field but granted complete latitude for the experimenter in his research endeavors, and to The Naval Air Systems Command which provided the required financial support.

BIBLIOGRAPHY

1. Craig, Richard A. The Upper Atmosphere Meteorology and Physics. New York and London: Academic Press, 1965.

2. Instructions for Radiosonde Set An/AMT-11C. Baltimore: The Bendix Corporation, 1966.

3. Manual of Radiosonde Observations (WBAN) Circular P (7th ed.), Washington: U. S. Government Printing Office, 1957.

4. Ney, Edward P., Raymond W. Maas, and William F. Huch, "The Measurement of Atmospheric Temperature," Journal of Meteorology, 18: 60-80, February, 1961.

5. Reynolds, Ralph D. and Roy L. Lamberth, "Ambient Temperature Measurements from Radiosondes Flown on Constant-Level Balloons," Journal of Applied Meteorology, 5-3: 304-307, June, 1966.

6. Andersen, LT Robert T., USN. "Thermal Effects on Baroswitches." Unpublished Bachelor's term paper, The U. S. Naval Postgraduate School, Monterey, California, 1966.

7. Caron, LCDR Reginald R., USN. "Radiosonde Battery Tests." Unpublished Bachelor's term paper, The U. S. Naval Postgraduate School, Monterey, California, 1966.

8. Latimer, J. R. "Radiosonde Intercomparison." Unpublished Master's Thesis, The University of Toronto, 1959.

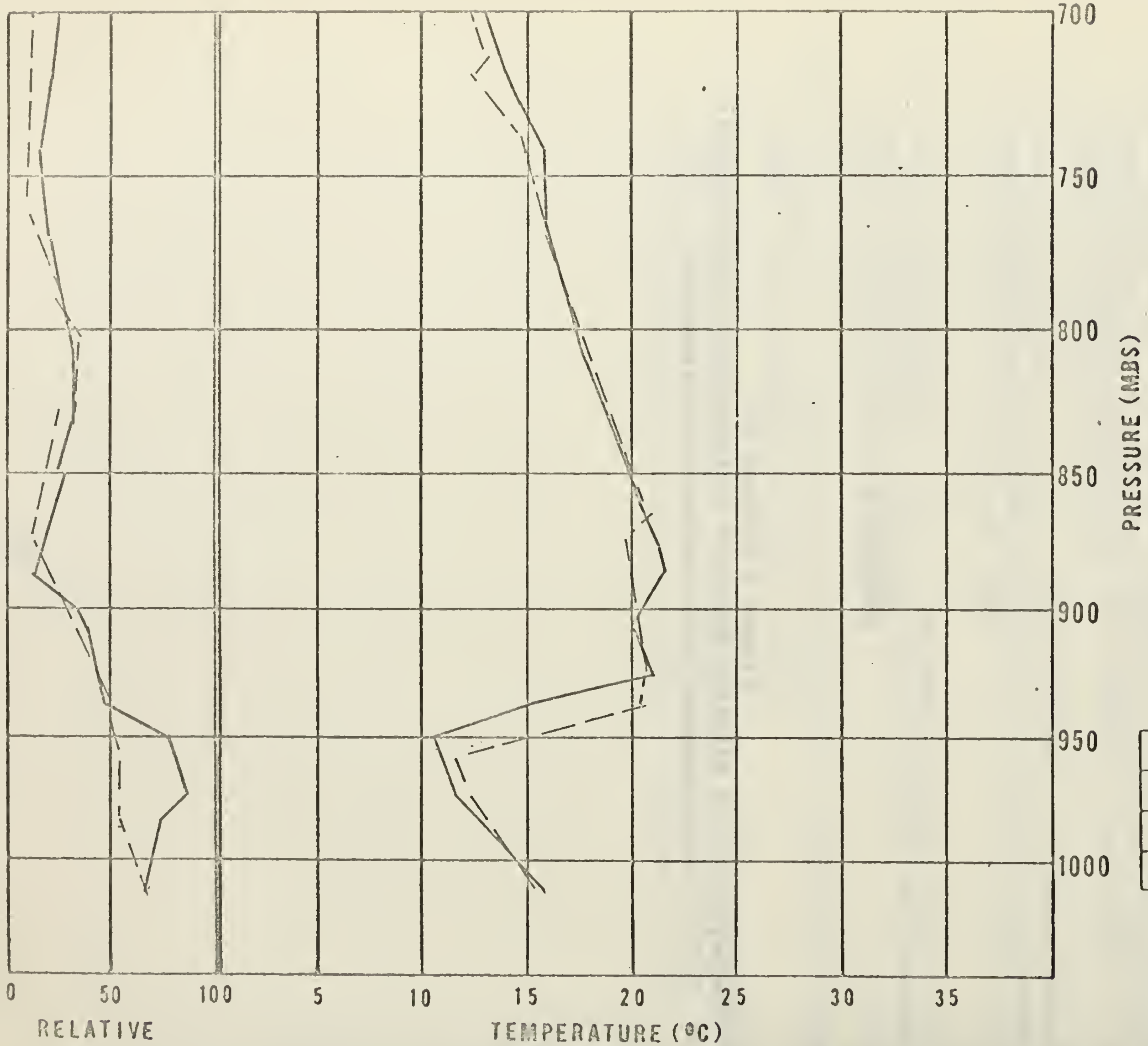
9. Witt, LT Charles D., USN. "An Investigation of Radiosonde Baroswitch Characteristics." Unpublished Bachelor's term paper, The U. S. Naval Postgraduate School, Monterey, California, 1966.

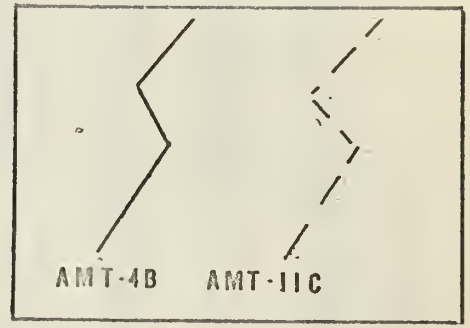
APPENDIX I

Plates I Through XV
Temperature and Relative Humidity Distribution in the Vertical
as Determined by Two Adjacent Radiosondes

U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.





CURVE LEGEND

Date and Release Time

	Year	Month	Day	Time
120 th Mer.	1966	Jul	18	1025PDT
	1966	Jul	18	1725Z
Ascension No. 36				

Plate I. Gross temperature difference at 940 mb caused by baroswitch disagreement.

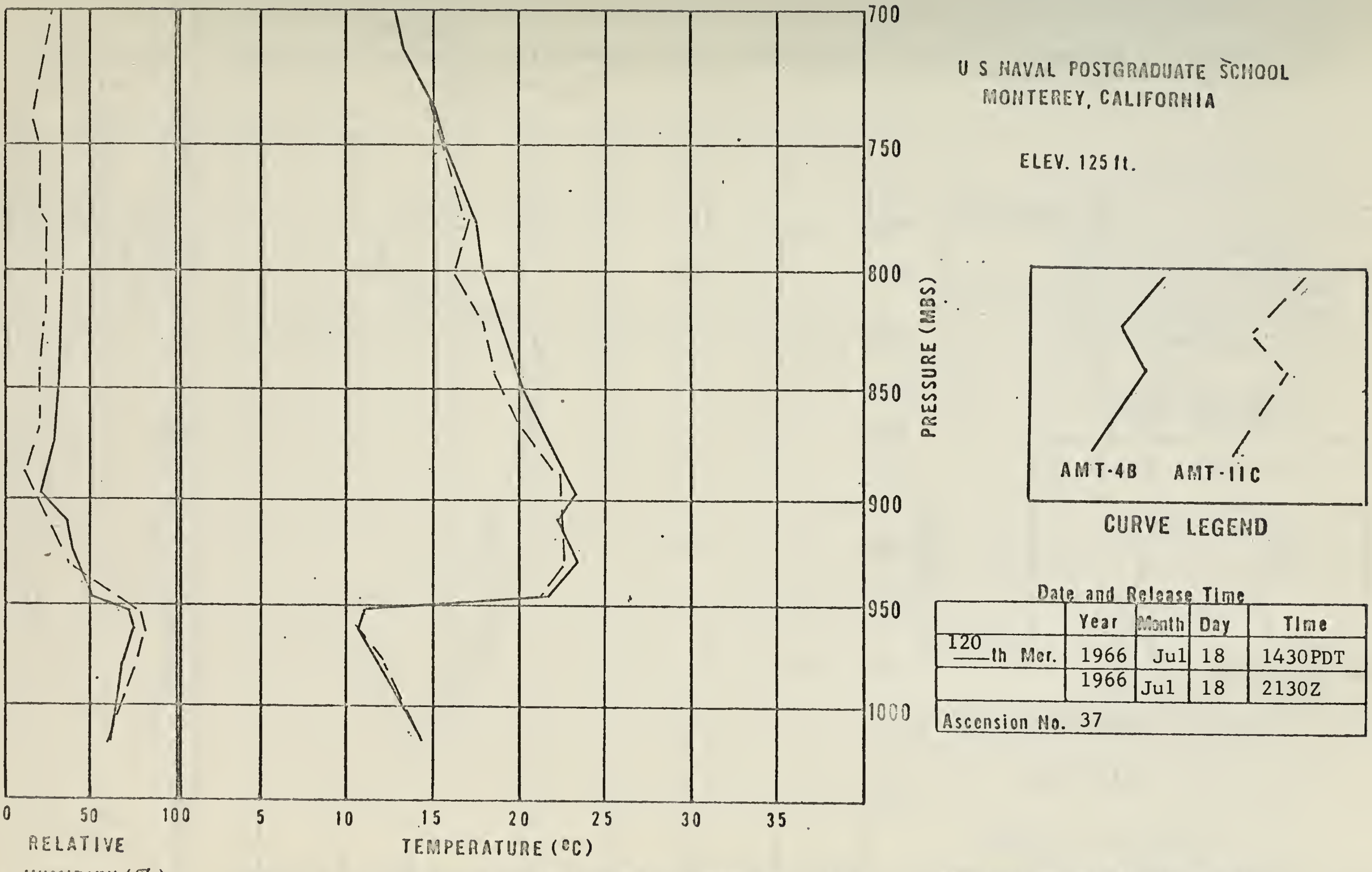
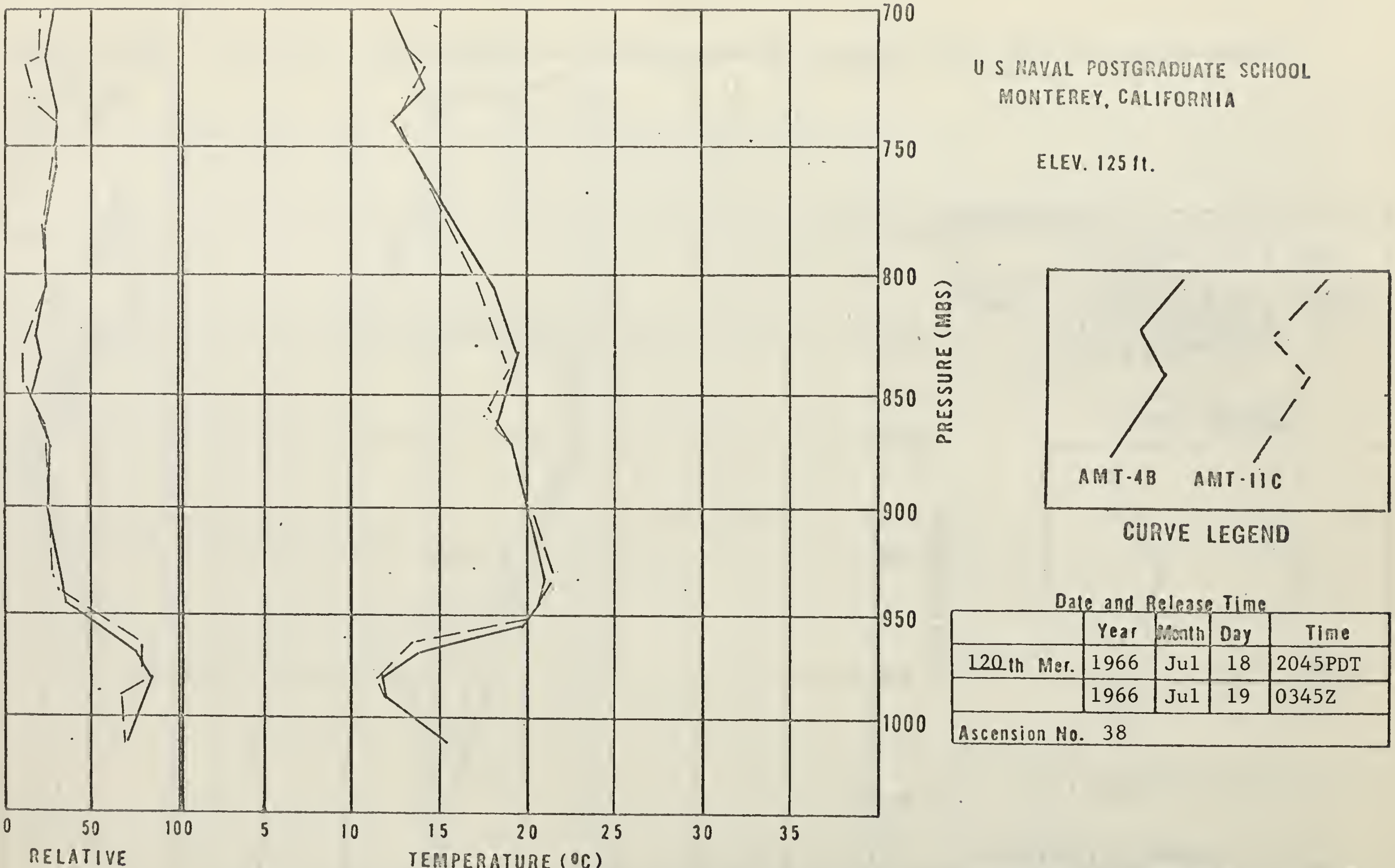


Plate II. Good temperature agreement through inversion with large differences above.



Date and Release Time

	Year	Month	Day	Time
120th Mer.	1966	Jul	18	2045PDT
	1966	Jul	19	0345Z
Ascension No. 38				

Plate III. Baroswitch differences caused disagreement between instruments at inversion bases and tops.

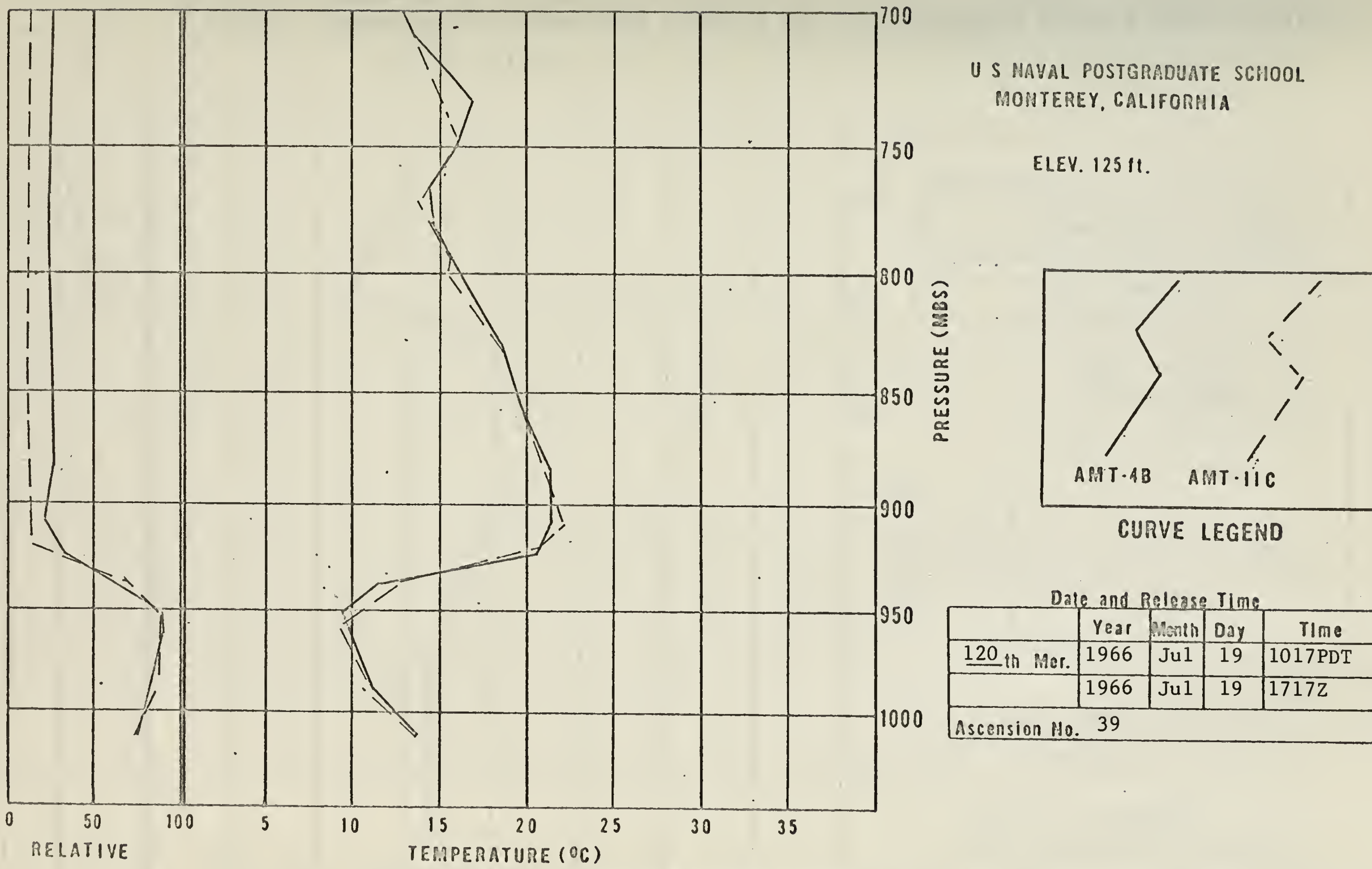
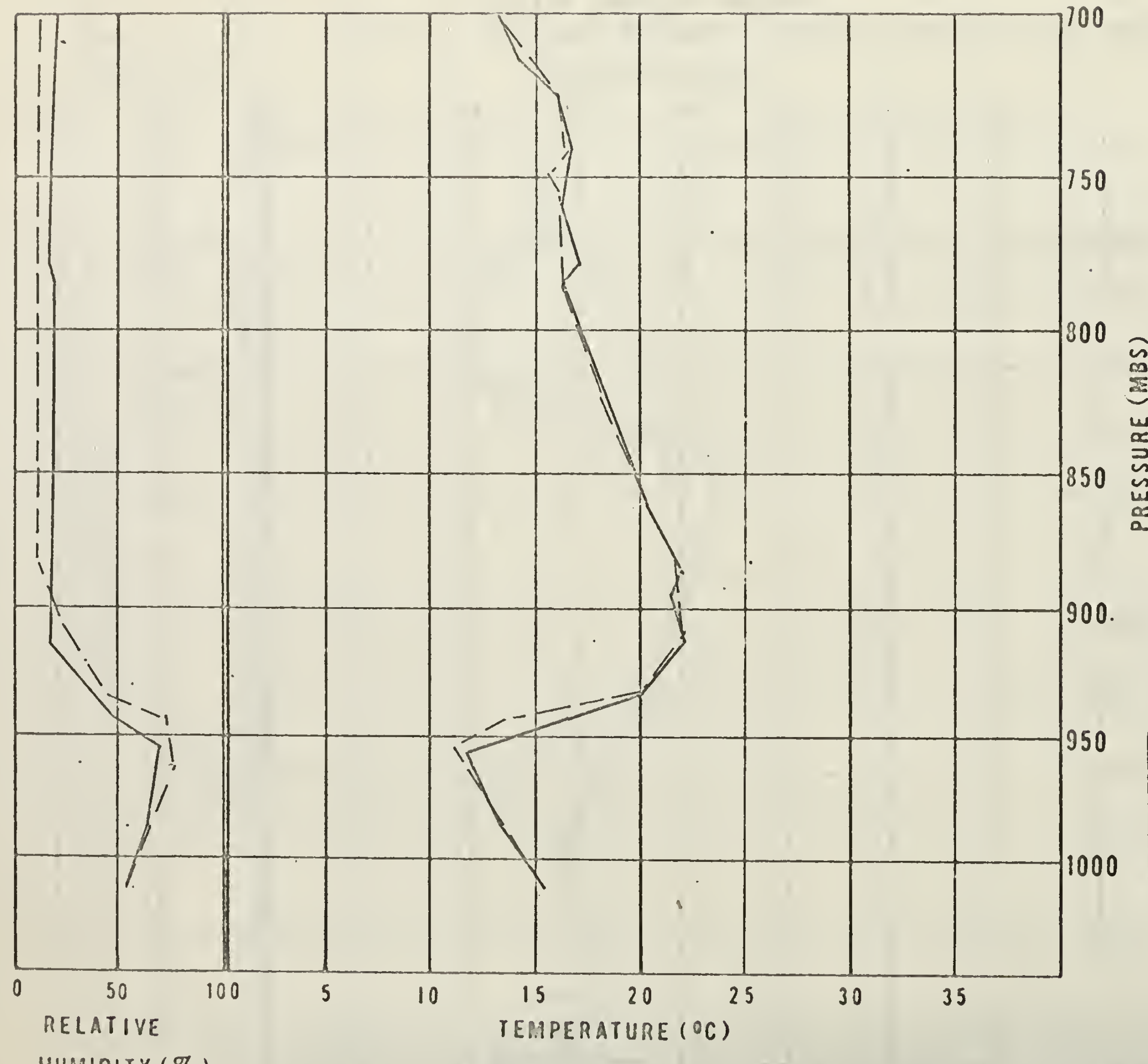
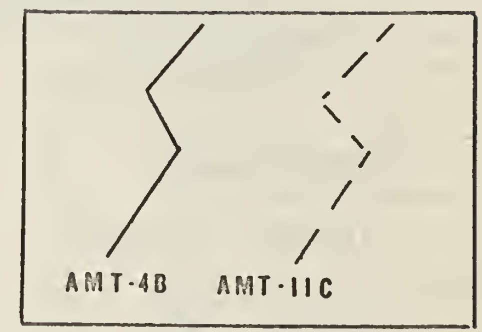


Plate IV. Relative Humidity difference above 930 mb characterizes failure of AMT-4B to respond to low humidity values.

U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.



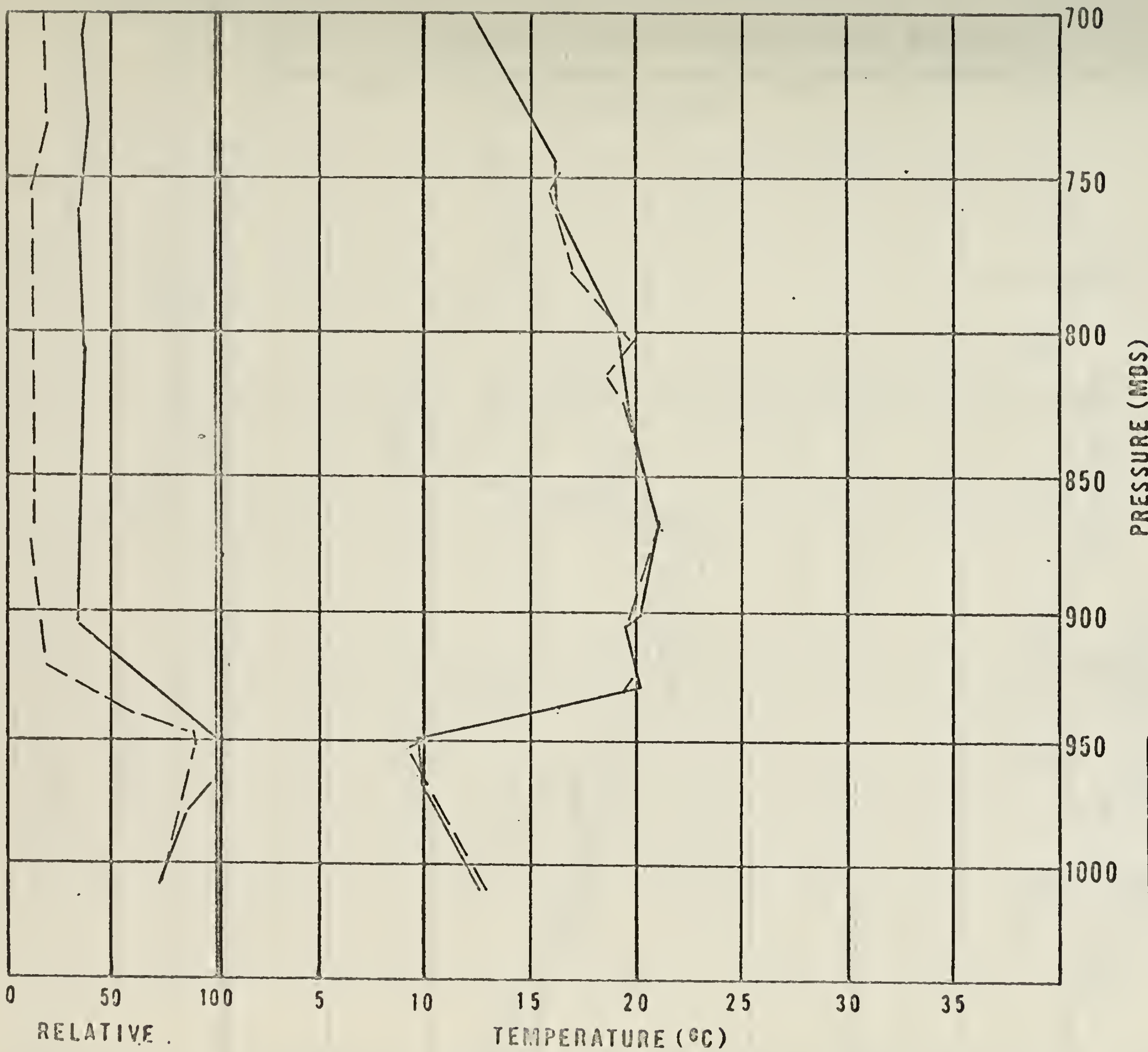


CURVE LEGEND

Date and Release Time

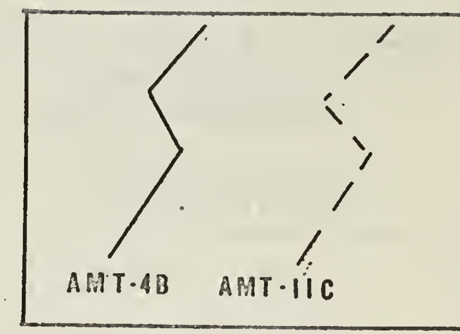
	Year	Month	Day	Time
120th Mer.	1966	Jul	19	1403PDT
	1966	Jul	19	2103Z
Ascension No. 40				

Plate V. Generally good temperature agreement but both instruments recorded small inversions independently.



U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.

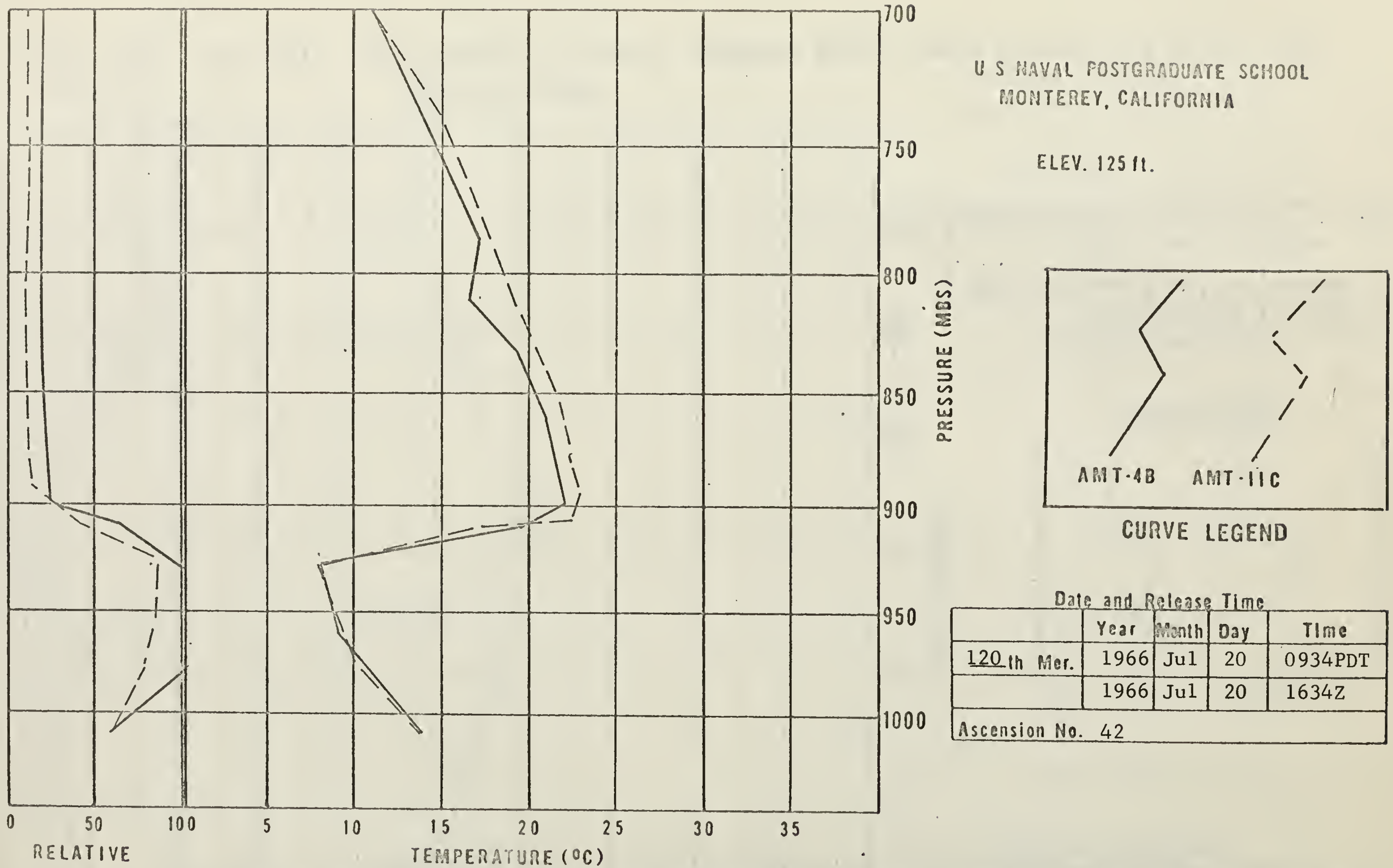


CURVE LEGEND

Date and Release Time

	Year	Month	Day	Time
120th Mer.	1966	Jul	19	1946PDT
	1966	Jul	20	0246Z
Ascension No. 41				

Plate VI. AMT-11C failed to indicate saturation when it passed through thick stratus layer.



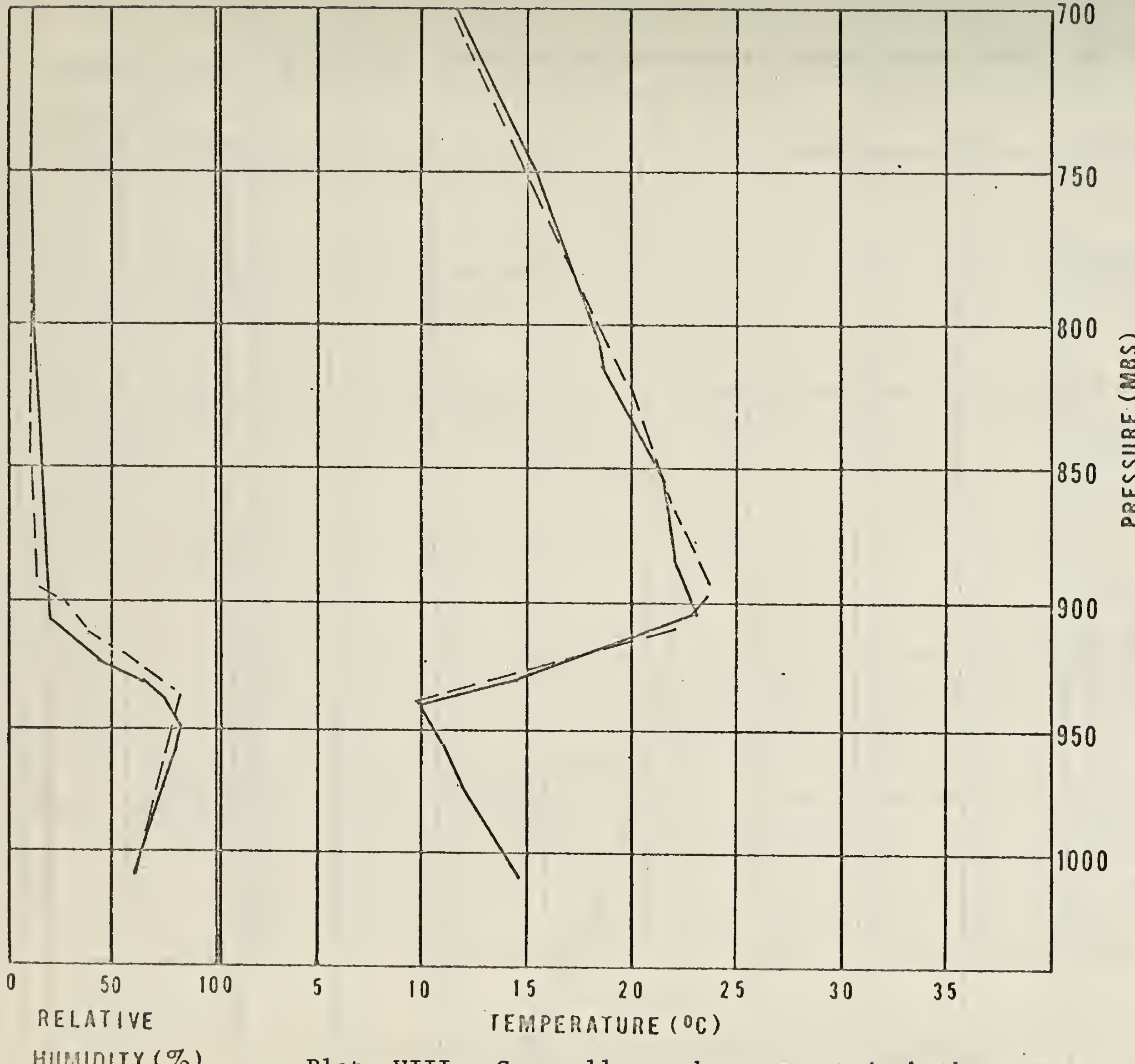
Date and Release Time

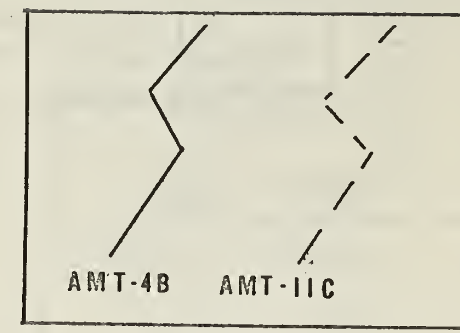
	Year	Month	Day	Time
120 th Mer.	1966	Jul	20	0934PDT
	1966	Jul	20	1634Z
Ascension No. 42				

Plate VII. AMT-11C again failed to indicate saturation in a thick stratus layer. Gross temperature differences occurred above 900 mb.

U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.



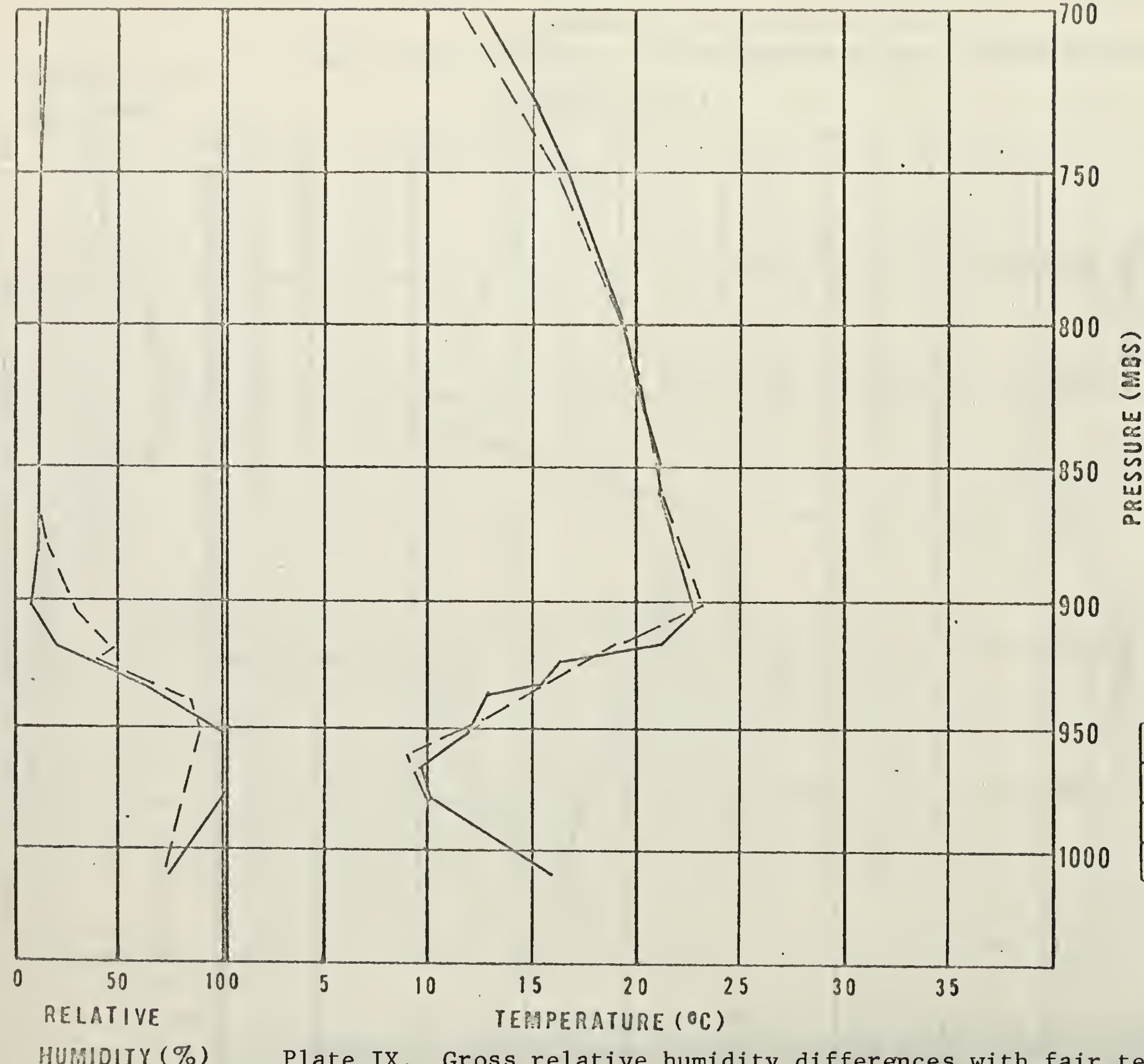


CURVE LEGEND

Date and Release Time

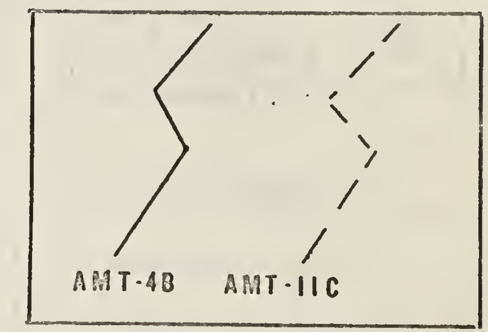
	Year	Month	Day	Time
120th Mer.	1966	Jul	20	1347PDT
	1966	Jul	20	2047Z
Ascension No. 43				

Plate VIII. Generally good agreement in both temperature and relative humidity with a ten-mb difference in top of inversion.



U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.

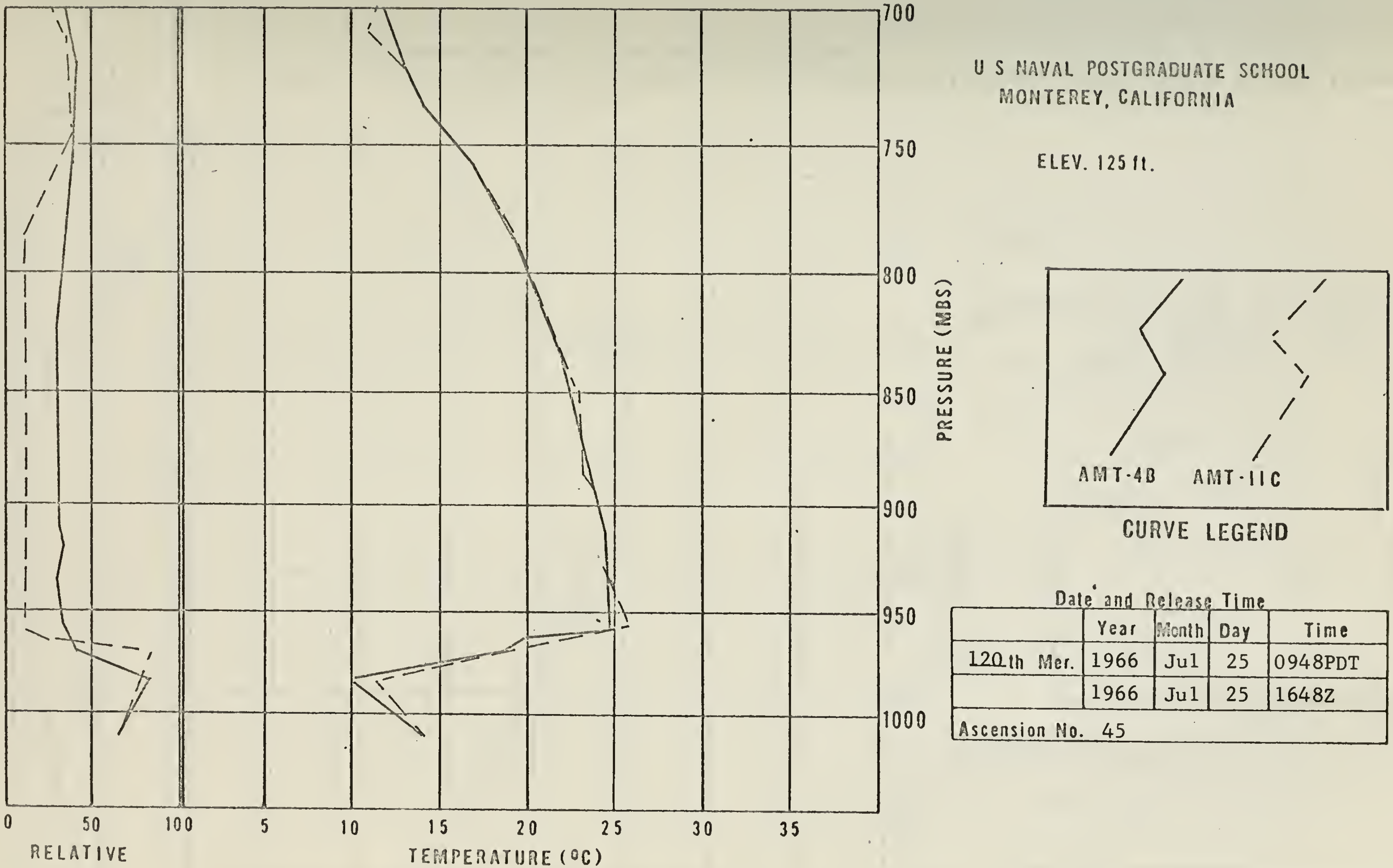


CURVE LEGEND

Date and Release Time

	Year	Month	Day	Time
120th Mer.	1966	Jul	20	1915PDT
	1966	Jul	21	0215Z
Ascension No. 44				

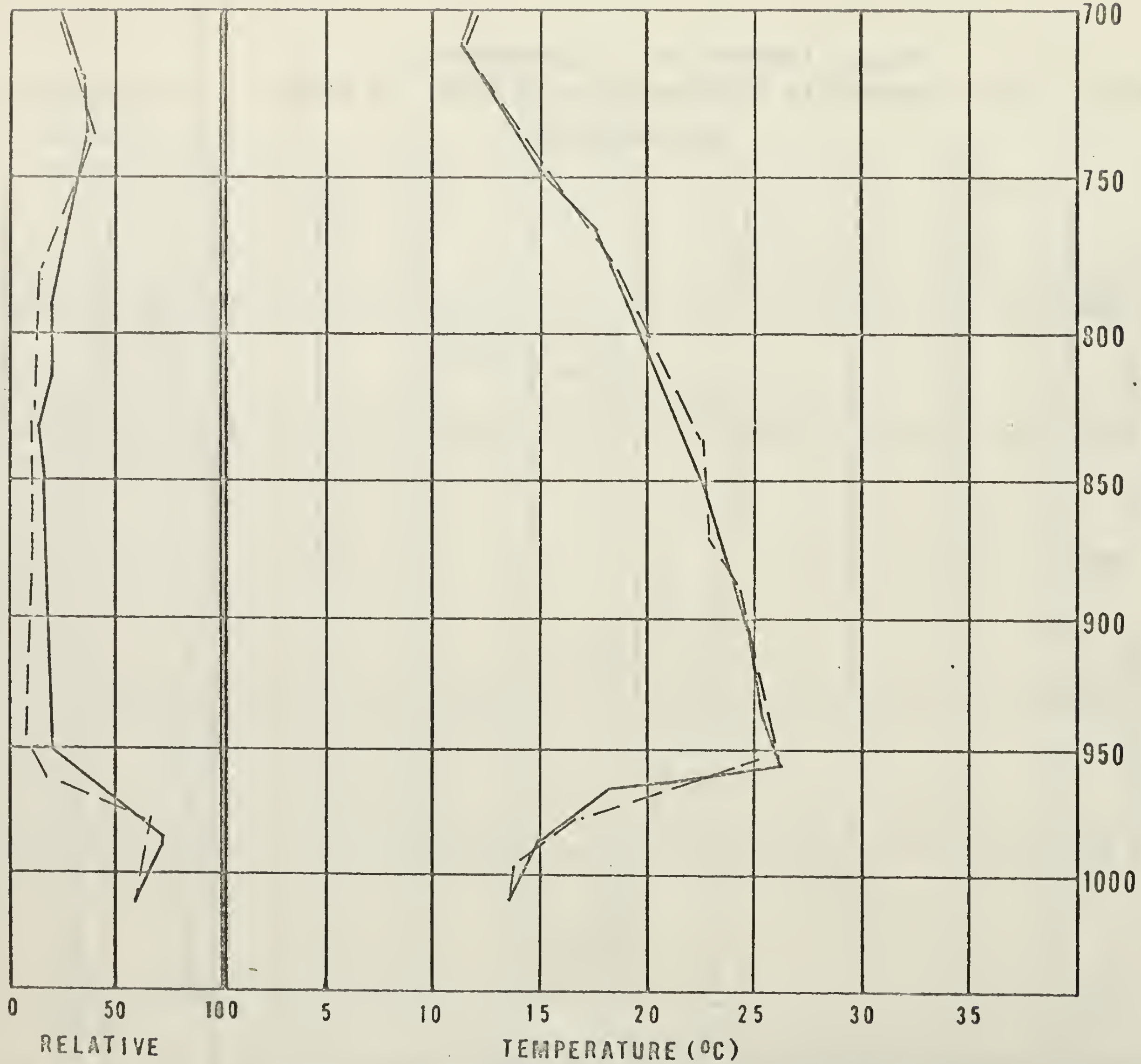
Plate IX. Gross relative humidity differences with fair temperature agreement.



Date and Release Time

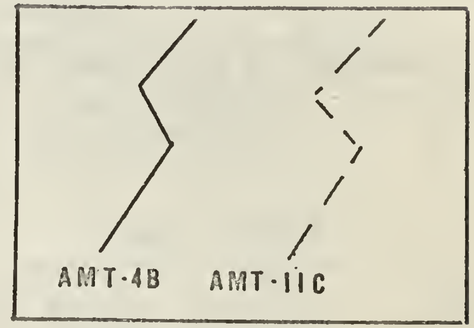
	Year	Month	Day	Time
120th Mer.	1966	Jul	25	0948PDT
	1966	Jul	25	1648Z
Ascension No. 45				

Plate X. Large relative humidity differences typify failure of carbon element used in AMT-4B to respond to low humidity values.



U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.



CURVE LEGEND

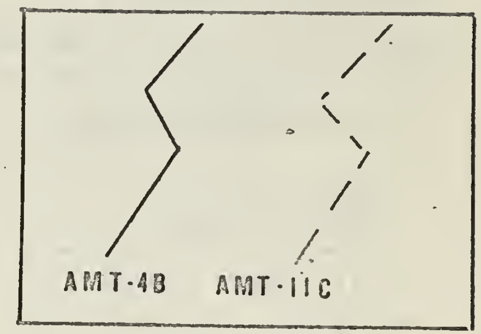
Date and Release Time

	Year	Month	Day	Time
120 th Mer.	1966	Jul	25	1328PDT
	1966	Jul	25	2028Z
Ascension No. 46				

Plate XI. Very good temperature agreement with humidity differences again caused by poor response of carbon element in low-humidity regime.

U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.



CURVE LEGEND

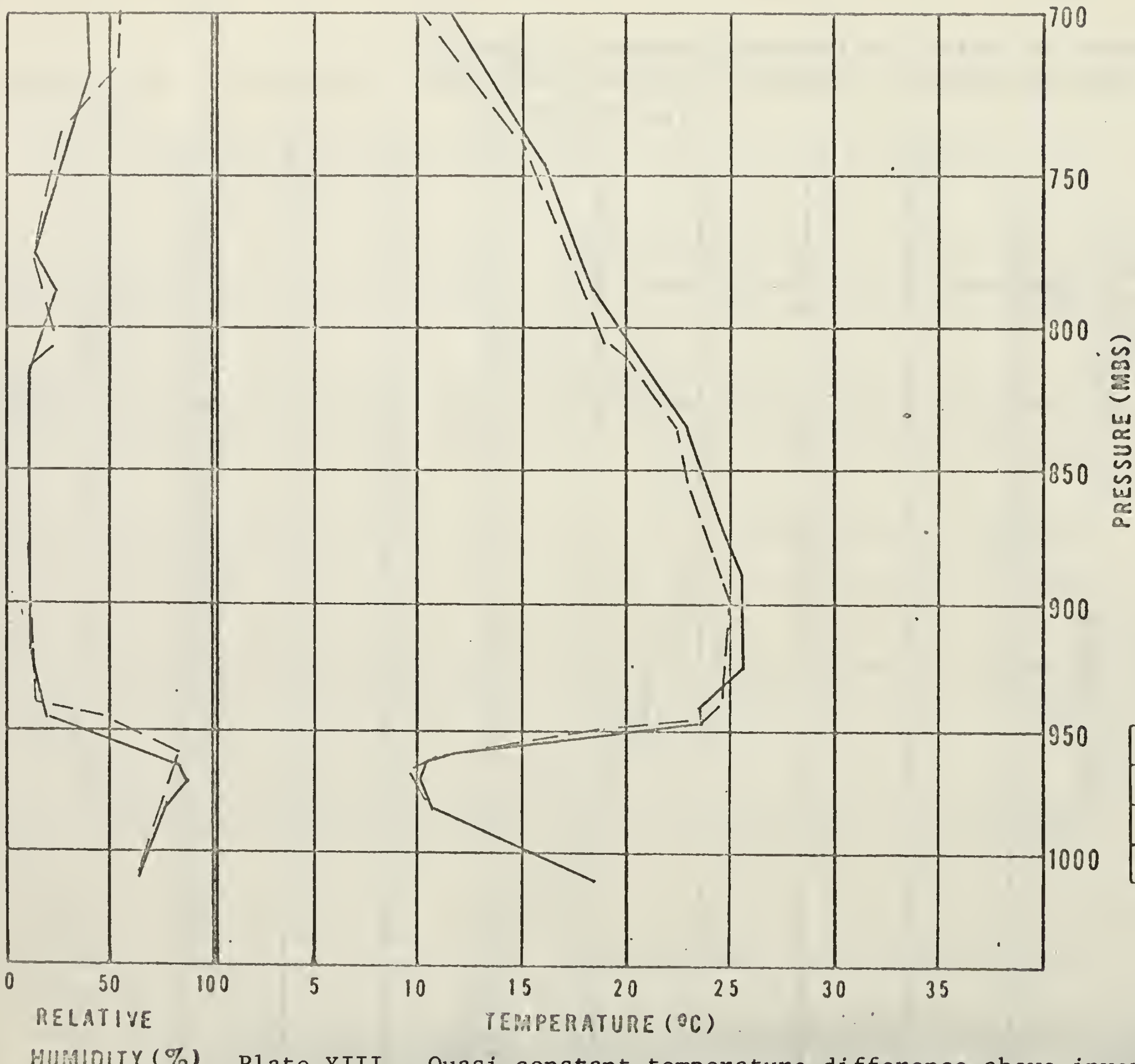
Date and Release Time

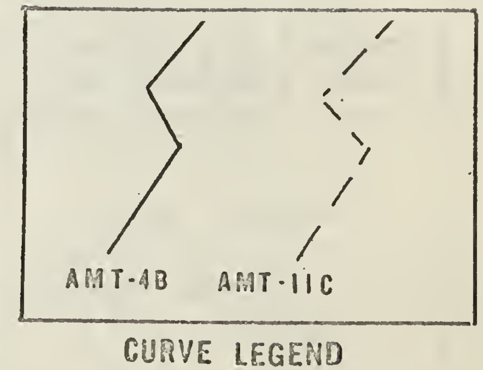
	Year	Month	Day	Time
120 th Mer.	1966	Jul	25	1919PDT
	1966	Jul	26	0219Z
Ascension No. 47				

Plate XII. Very good temperature agreement through inversion; very low humidity values from the AMT-4B resulted from partial failure of humidity element.

U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.





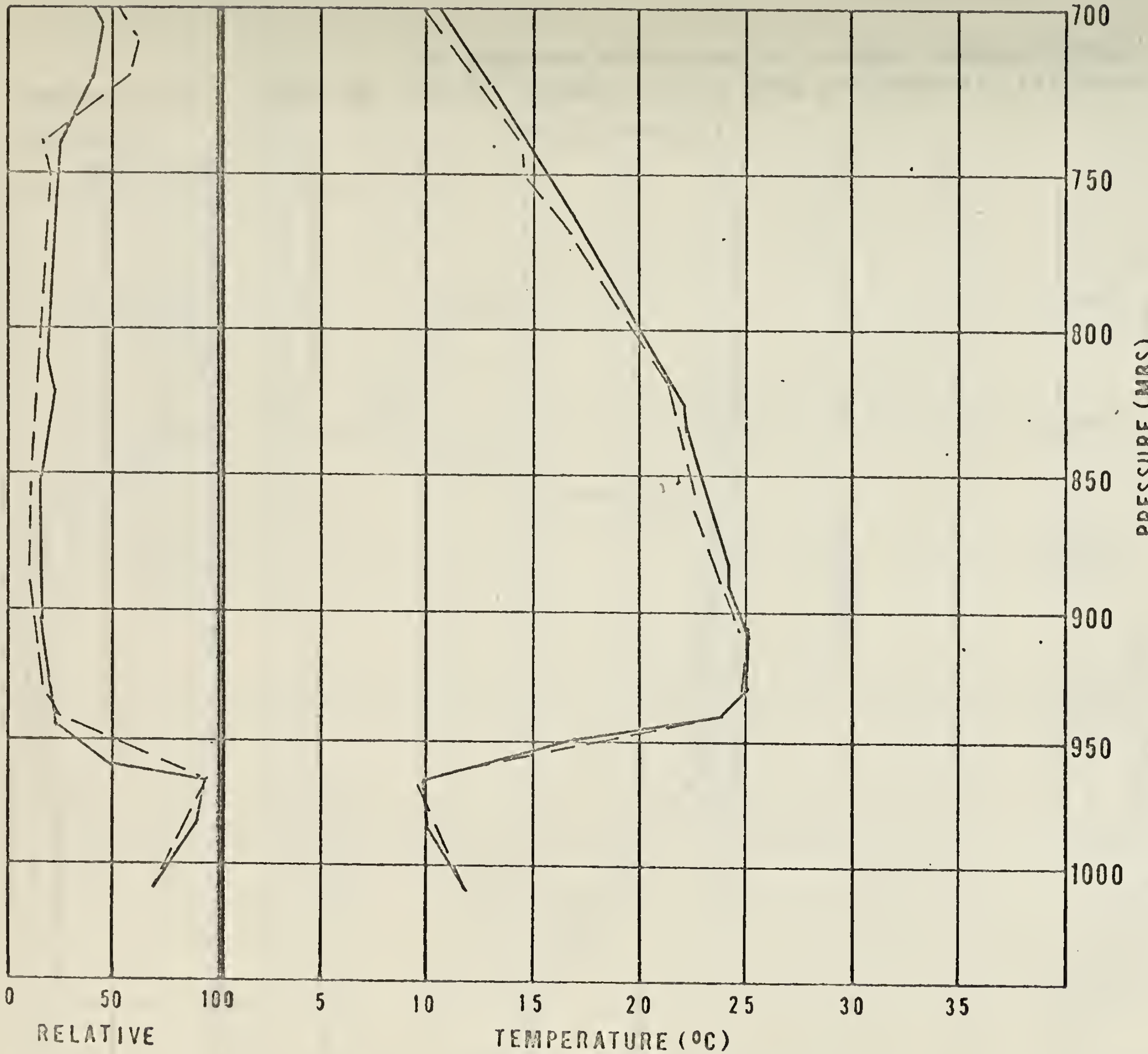
Date and Release Time

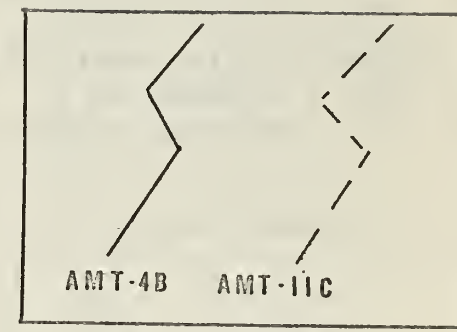
	Year	Month	Day	Time
120 th Mer.	1966	Jul	26	1520PDT
	1966	Jul	26	2220Z
Ascension No. 48				

Plate XIII. Quasi-constant temperature difference above inversion. Note greater response to increasing humidity at 720-mb level by the lithium-chloride element of the AMT-11C.

U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.





CURVE LEGEND

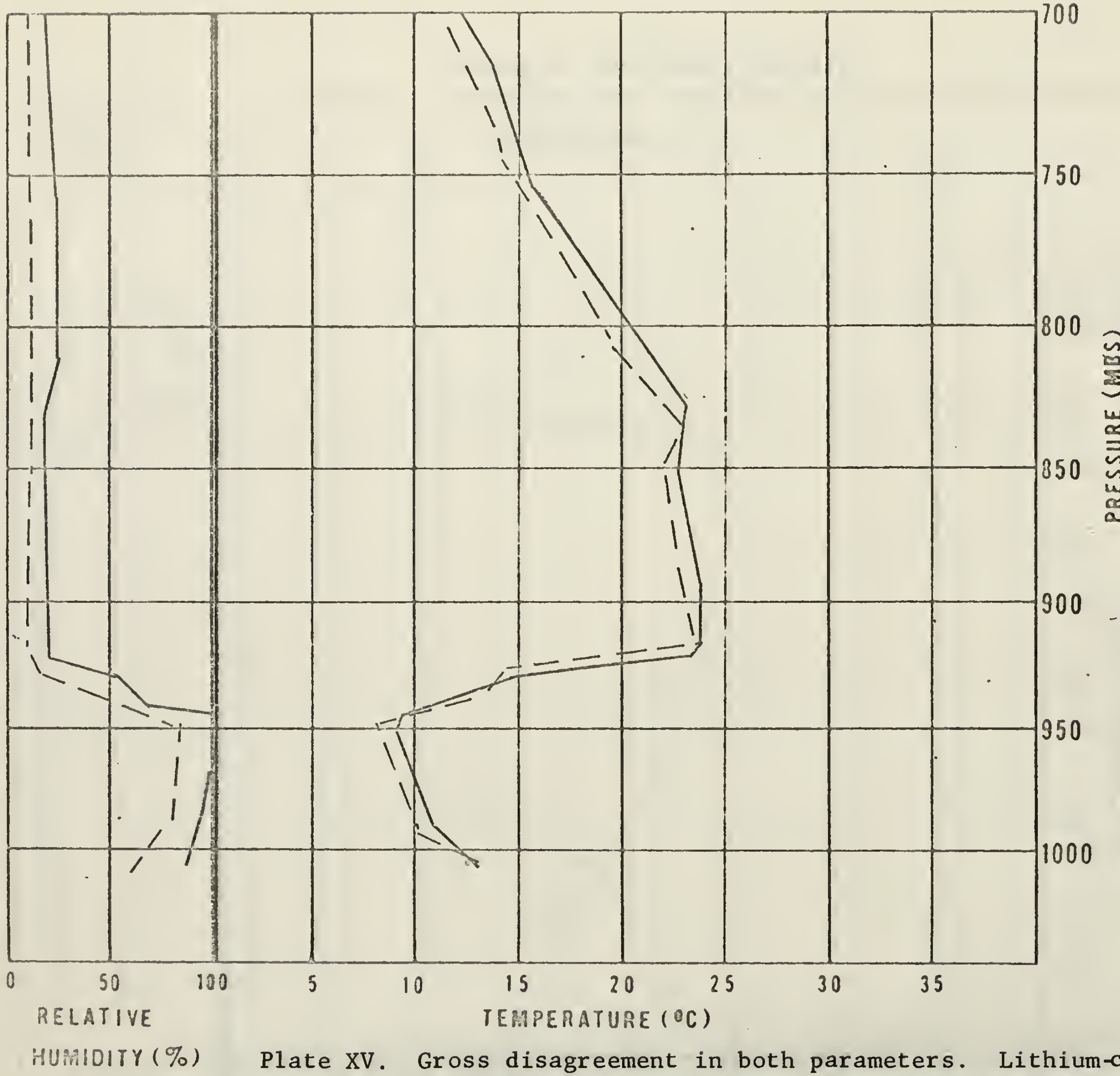
Date and Release Time

	Year	Month	Day	Time
120th Mer.	1966	Jul	26	1900PDT
	1966	Jul	27	0200Z
Ascension No. 49				

Plate XIV. Generally good agreement but the lithium-chloride element again gave the greater response to increasing humidity.

U S NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

ELEV. 125 ft.



CURVE LEGEND

Date and Release Time

	Year	Month	Day	Time
120 th Mer.	1966	Jul	27	0958PDT
	1966	Jul	27	1658Z
Ascension No. 50				

Plate XV. Gross disagreement in both parameters. Lithium-chloride humidity element again failed to indicate saturation in a thick stratus layer.

APPENDIX II

Instructions for Encoding Radiosonde Data for Reduction by Electronic Computer

TITLE: GMD - Combined GMD1 and GMD2 Rawinsonde Reduction.

CATEGORY: Scientific Data Reduction
PROGRAMMER: Yoshito K. Yamamura
REVISION: Revised for 3100 Operation - April 1966 - Y. K. Yamamura
REVISION: Introduction of new RH equations - July 1966 - E. M. Davies, AGCM

PURPOSE

The GMD program provides a tabulation of pressure, temperature, relative humidity, wind direction and wind speed from the input of data from a Rawinsonde observation. In addition to the above parameters, speed of sound, refractive index in N units, dew point and mixing ratio are computed and output. Three forms of data are produced from the program. They are (1) Data at Standard Pressure Levels (2) Data at Significant Levels, and (3) Interpolation to a preselected altitude increment. The altitude increment is selected at input time. Data produced on various output media is in suitable form for storing as climatological data and for immediate transmittal via teletype.

DESCRIPTION

The following information concerning various revisions is entered in this document to preserve historical sequence of the program.

New humidity equations were prepared by Y. K. Yamamura and inserted in the program in July 1966. At this time title input data was completely generalized so the program could be used by any station. Dew point computations can no longer produce an output (due to truncation factors) that is higher than temperature. Data input procedures were revised to take advantage of the greater power of the 3100 reportoire and to eliminate special terminating data cards.

This program is written in FORTRAN language and consists of four overlays and three segments. The first section of the program contains overlays one, two, three and MAIN. This section initilaizes relative humidity equations and reads data into the system. It computes all parameters for each data card level and produces output to tape unit 02. Three following sections are on overlay four, segment one, two and three. These sections interpolate data from tape unit 02 and produce Standard Pressure level output, Significant level output and Altitude increment output.

Output options, selectable by JUMP KEY, can be any one or all of the following: Printer, magnetic tape (Tape unit 01), and paper tape punch.

EQUIPMENT ENVIRONMENT

CDC 3100 Computer system.

Four magnetic tape units, line printer, card reader, and paper tape punch.

Tape units are designated as logical unit 63 - Systems tape
logical unit 02 - Intermediate output
logical unit 01 - final output
logical unit 50 - overlay tape.

OPERATING INSTRUCTIONS

Preparation of Input Data

a. The preparation of input data for Rawinsonde reduction has been a standard procedure in Geophysics Division for a number of years. Many personnel are familiar with the old formats and they must be especially careful to review this section to insure that the input data for the revised program is in the proper form. To provide accurate and rapid handling of input data it is essential that the data be prepared properly <u>the first time</u> and is in the right form for the computer.

b. These instructions apply only to those rawinsonde ascents which utilize the ML-476 carbon humidity element and either ML-406 or ML-419 temperature element.

c. Recorder records will be evaluated as outlined in Circular "P" and Circular "O" except as indicated below.

1. Levels will be evaluated at 1 minute intervals for the entire ascent.
2. Significant levels may be inserted between evaluated one minute intervals.
3. The surface elevation angle must be reported as 0000. The surface azimuth angle must be the azimuth from antenna to release point.
4. When preparing teletype tapes for card production, each line must end by punching one space, two carriage returns and one line feed.
5. Decimal points, minus signs and plus signs may not be imbedded in the data fields.
6. Corrections to tapes may be made by backspacing over the error and blanking out with the letters punch, each error. This must be followed by one figures punch to get the teletype in upper case mode.

d. In the following details of the input format, there are some variations between GMD-1 and GMD-2. These variations will be shown by a note beside the instruction. Changed items will be shown by an asterisk (*).

SYMBOLIC FORM OF INPUT DATA

NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
0000000000000000000000000000000

HHH DDD FF $t_c t_c t_c$ $f_c f_c$ RRRRR IIIII G (GMD-1 format)
HHH DDD FF $t_c t_c t_c$ $f_c f_c$ ppppp IIIII G (GMD-2 format)

fff ttt PPPPP EEEE AAAA MM (GMD-1 format)
fff ttt rrrrrr eeee aaaaa MMM (GMD-2 format)

```
fff ttt PPPPP EEEE AAAA MMM
fff ttt rrrrrr EEEE AAAAA MMM

etc. . . . . . . . . . . . . . .

fff ttt PPPPP EEEE AAAA MMM
fff ttt rrrrrr EEEE AAAAA MMM

                  1                        (GMD-1 Humidity drop-out col 18)
                    1                      (GMD-2 Humidity drop-out col 20)

ttt PPPPP EEEE AAAA MMM                    (GMD-1 after dropout)
ttt rrrrrr EEEE AAAAA MMM                  (GMD-2 after dropout)

ttt PPPPP EEEE AAAA MMM
ttt rrrrrr EEEE AAAAA MMM

etc. . . . . . . . . . . . .
```

No special terminating format is required. See notes below.

e. Preparation of data for tape and cards.

```
*NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
*DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
*0000000000000000000000000000000
```

These symbolic forms denote free fields for input data extending from column 2 of the card to column 32. The title of the sounding is entered on these cards.

EXAMPLE: STATION, PT MUGU
0952Z 18 JULY 1966
FOR OP.NO. 7876 7654 6543

Data cannot be entered in column 1. When preparing tape this data will be entered in the format required by the rawinsonde operators. When the cards are punched, the card punch will automatically start at column 7. The computer operator will recut these three cards and put the data in the proper field starting with column 2.

HHH Height of release point in feet MSL

DDD Surface wind direction in degrees true. Enter calm as 000, North = 360.

FF Surface wind speed in knots. Enter calm as 000.

$t_c t_c t_c$	Temperature lock-in value at baseline time. This is the temperature value opposite 37.6 ordinates when the 223B computer is locked in with 25.0°C falling between 66.5 and 68.9 ordinates.
$f_c f_c$	Relative humidity lock-in value. This is the relative humidity corresponding to an ordinate value of 46.0 at a temperature of -40.0°C on the 223B computer.
*RRRRR	GMD-1 only. Horizontal distance from antenna to release point in yards and tenths. EXAMPLE: 100 yds = 01000 50 yds = 00500
ppppp	GMD-2 only. Surface pressure to tenths of millibars, entered as five digits with decimal omitted. EXAMPLE: 1011.5 Mb. = 10115 988.6Mb. = 09886
*IIIII	Interpolated altitude increment required. This is normally entered as 01000 for 1000 feet increments. It may be changed to 00500 for 500 feet or 02000 for 2000, etc. as the requirement demands.
*G	A single digit number denoting whether GMD-1 equipment or GMD-2 equipment was used. Entered as 1 or 2 respectively.
fff	Relative humidity ordinate value entered as a three digit number to the nearest tenth. Values at Geophysics Division will be reported for all levels to 105 contacts regardless of the temperature. Missing humidity will be reported as 900.
ttt	Temperature ordinate value entered as a three digit number to the nearest tenth. No provision is made for missing values. Interpolated values will be entered when the trace is missing. Use discretion and Circular "P" for the maximum number of levels that may be interpolated.
ppppp	GMD-1 only. Pressure at the level. This is entered as a five digit number in millibars and tenths. EXAMPLE: 1015.8 = 10158; 426.0 = 04260; 27.0 = 00270.
rrrrrr	GMD-2 only. Slant range from radar entered as six digits to the nearest yard.
EEEE	Elevation angle entered as four digits according to the following conventions. a. To nearest tenth degree whenever the angle is greater than 20 degrees. b. To nearest five-hundredth when angle is 15.0 to 20.0 degrees. c. To nearest one-hundredth when angle is below 15.0 degrees. d. Missing angles, limiting angles and angular

data for significant levels selected between whole minutes will be entered as 0000.
NOTE: Elevation angles of less than 12.0 degrees will be smoothed before being punched in accordance with Paragraph 2412.1 of Circular "O".

AAAA	GMD-1 only. Azimuth angle entered in four digits to the nearest tenth degree. Missing angles, limiting angles and angles for significant levels selected between whole minutes will be entered as 0000. Enter true north as 3600.
AAAAA	GMD-2 only. Azimuth angle entered in five digits to the nearest one-hundredth. Missing angles, limiting angles and significant levels selected between whole minutes will be entered as 00000. 36000 = NORTH.
MMM	Time in minutes after release entered in three digits to nearest tenth. Filling zeros must be used in front of significant digits.

EXAMPLES:

Surface is always entered as	000
minute 1	010
minute 11	110
minute 11.8	118
minute 100	000
minute 106.5	065

f. The humidity "dropout" card is a card with a single 1 entered in column 18 or column 20 for GMD-1 or GMD-2 respectively. This card is inserted to indicate that no further humidity data can be expected and the card format changes as indicated in the symbolic form.

Following the dropout card all data is left-adjusted to take up the columns that were assigned to humidity data as indicated in the symbolic form above.

g. The last level that is evaluated will be the last card of the data deck. This level can be significant (Ending between a whole minute) or ending on a whole minute. No zero fill or extra cards are required.

APPENDIX III

Meteorological Data Print-out from
CDC-3100 Electronic Computer

RAWINSONDE DATA (GMD- 1)
STATION, PGS MONTEREY

FOR FLIGHT NO. T16
1758Z 25 JAN 1966

STANDARD PRESSURE LEVELS

PRESS	H(M)	H(FT)	T	TD	RH	DDD	FF(M)	KTS
1016.5	38	125	9.4	.8	55	360	0	0
1000.0	174	572	8.6	.2	56	0	0	0
950.0	597	1959	6.8	-0.1	62	157	2	4
900.0	1041	3414	6.2	-8.9	33	148	4	8
850.0	1508	4948	4.7	-13.1	26	180	9	18
800.0	2000	6563	2.5	-14.1	28	192	7	14
750.0	2519	8265	-0.6	-19.0	24	194	5	9
700.0	3067	10063	-3.5	-17.3	34	198	5	9
650.0	3650	11974	-7.3	-22.0	30	282	16	31
600.0	4267	14001	-11.6	-26.6	28	191	9	18
550.0	4929	16172	-15.7	-30.9	26	223	8	16
500.0	5643	18512	-18.7	-34.9	22	236	10	20
450.0	6418	21056	-24.6	-34.4	40	250	13	24
400.0	7266	23838	-29.5	-35.3	58	266	16	31
350.0	8204	26915	-37.9	-46.4	41	276	15	30
300.0	9247	30337	-47.0	-53.6	47	277	20	40
250.0	10426	34207	-56.9	-63.6	44	305	32	63
200.0	11857	38901	-54.3	-65.5	25	279	39	75
175.0	12709	41697	-55.2	-67.4	21	281	49	96
150.0	13691	44919	-56.2	0	0	278	58	112
125.0	14847	48710	-53.1	0	0	292	26	50
100.0	16257	53337	-60.3	0	0	290	23	45
80.0	17652	57914	-59.8	0	0	315	12	24
70.0	18489	60659	-57.3	0	0	8	6	11
60.0	19462	63851	-56.6	0	0	62	7	14
50.0	20617	67643	-56.2	0	0	302	3	5
40.0	22037	72301	-55.3	0	0	33	8	15

30.0	23876	78332	-55.1	0	0	84	8	17
25.0	25040	82152	-54.1	0	0	63	12	22
20.0	26488	86902	-49.8	0	0	66	16	31
15.0	28370	93076	-50.0	0	0	54	4	9
10.0	31011	101742	-49.3	0	0	75	11	21
7.0	33384	109528	-46.2	0	0	332	8	15
5.0	35617	116854	-45.8	0	0	307	3	6
4.0	37109	121749	-43.9	0	0	275	7	13
3.0	39052	128124	-41.7	0	0	294	13	25
2.0	41838	137265	-38.1	0	0	245	41	80

SIGNIFICANT LEVELS

P	T	TD	H(M)	H(FT)	N
1016.5	9.4	.8	38	125	309
988.0	8.0	-0.2	273	897	301
959.0	6.7	.8	519	1702	297
933.0	7.1	-1.8	745	2444	284
833.0	4.6	-14.3	1672	5486	243
806.0	2.9	-12.9	1939	6363	238
710.0	-3.4	-17.0	2954	9691	213
686.5	-3.6	-17.6	3220	10565	206
598.0	-11.8	-26.8	4293	14083	181
534.0	-17.2	-30.1	5151	16899	165
499.0	-18.7	-35.1	5657	18560	154
483.6	-21.9	-34.9	5889	19322	151
466.0	-22.7	-33.8	6162	20216	146
448.0	-24.8	-34.5	6450	21160	142
433.0	-26.5	-32.7	6697	21971	139
358.0	-36.4	-45.6	8047	26399	118
278.0	-51.6	-58.3	9745	31971	98
244.0	-57.8	-64.5	10579	34707	88
235.5	-53.8	-61.1	10804	35448	83
160.0	-56.4	-69.9	13279	43568	57
152.5	-55.5	0	13585	44570	54
134.5	-59.0	0	14378	47172	49
129.0	-53.6	0	14643	48042	46

124.0	-53.0	0	14898	48877	44
48.0	-55.5	0	20877	68495	17
10.6	-51.2	0	30630	100493	4
3.0	-41.7	0	39052	128124	1
2.0	-38.1	0	41838	137265	1

ALTITUDE INTERVAL 1000 FT.

H	DDD	FF	T	TD	P	RH	W	N	D	CS
125	360	0	9.4	.8	1016.5	55	4.0	309	1250.36	655
1000	149	2	7.8	-0.1	984.2	57	3.9	300	1217.44	653
2000	155	4	6.9	-0.2	948.5	61	4.0	292	1177.30	652
3000	136	6	6.5	-5.8	913.9	42	2.8	273	1136.70	651
4000	166	14	5.8	-11.9	880.6	27	1.8	256	1098.48	651
5000	181	18	4.7	-13.2	848.3	26	1.6	248	1062.61	649
6000	188	16	3.6	-13.5	817.1	28	1.7	240	1027.64	648
7000	198	12	1.6	-16.7	786.9	24	1.3	231	996.98	645
8000	198	10	-0.1	-19.3	757.6	22	1.1	222	966.15	644
9000	184	8	-1.9	-18.0	729.2	28	1.2	216	935.66	642
10000	196	9	-3.5	-17.2	701.7	34	1.4	211	905.78	640
11000	289	38	-4.7	-19.3	675.2	32	1.3	203	875.73	639
12000	280	30	-7.3	-22.0	649.4	30	1.0	195	850.60	635
13000	143	60	-9.5	-23.8	624.4	31	.9	188	824.75	632
14000	188	18	-11.6	-26.5	600.2	28	.7	182	799.02	630
15000	213	17	-13.4	-28.7	576.8	26	.6	175	773.29	628
16000	220	16	-15.3	-31.1	554.1	25	.5	169	748.46	626
17000	234	17	-17.3	-30.3	532.1	32	.6	164	724.25	623
18000	235	20	-18.4	-33.1	510.9	26	.5	158	698.54	622
19000	238	20	-20.5	-35.0	490.4	26	.4	152	676.07	619
20000	246	22	-22.5	-34.1	470.6	34	.5	147	653.90	616
21000	250	24	-24.4	-34.4	451.4	39	.5	143	631.93	614
22000	254	26	-26.5	-32.7	432.9	57	.6	139	611.34	612

23000	264	30	-28.4	-33.2	415.0	64	.6	134	590.48	609
24000	266	31	-29.9	-35.9	397.7	56	.5	128	569.22	608
25000	273	28	-32.4	-40.4	381.0	46	.3	124	551.29	605
26000	279	27	-35.1	-44.2	364.8	39	.2	120	533.82	601
27000	275	30	-38.0	-46.5	349.2	41	.2	116	517.23	598
28000	275	36	-40.5	-48.1	334.0	45	.1	112	500.06	594
29000	275	38	-43.0	-49.7	319.4	49	.1	108	483.47	591
30000	275	39	-45.9	-52.5	305.2	48	.1	104	467.82	587
31000	281	40	-48.8	-55.6	291.5	46	.1	101	452.64	583
32000	291	40	-51.5	-58.2	278.3	45	.1	98	437.36	580
33000	300	43	-54.1	-60.9	265.5	44	0	94	422.19	577
34000	305	60	-56.4	-63.1	253.1	44	0	90	406.68	574
35000	304	67	-56.5	-63.4	241.3	43	0	86	388.03	574
36000	296	60	-53.0	-60.9	230.1	39	0	81	364.09	578
37000	295	52	-52.2	-61.7	219.5	32	0	78	346.12	579
38000	284	64	-54.2	-64.9	209.4	26	0	74	333.22	576
39000	279	75	-54.4	-65.5	199.7	25	0	71	318.04	576
40000	277	84	-55.3	-66.8	190.5	23	0	68	304.52	575
41000	277	97	-55.6	-67.5	181.6	21	0	65	290.83	575
42000	283	92	-55.1	-67.4	173.2	20	0	62	276.56	576
43000	288	80	-55.6	-68.8	165.1	18	0	59	264.38	575
44000	278	99	-56.1	0	157.4	0	0	56	252.67	574
45000	278	112	-56.2	0	150.1	0	0	53	240.98	574
46000	285	107	-57.8	0	143.1	0	0	52	231.40	572
47000	290	73	-58.8	0	136.3	0	0	50	221.50	570
48000	292	58	-54.5	0	129.9	0	0	47	207.08	576
49000	292	48	-53.0	0	124.0	0	0	44	196.14	578
50000	284	45	-55.4	0	118.2	0	0	42	189.16	575
51000	277	46	-57.6	0	112.7	0	0	41	182.16	572
52000	275	46	-59.2	0	107.4	0	0	39	174.88	570
53000	284	48	-60.2	0	102.3	0	0	37	167.36	568
54000	297	38	-59.6	0	97.5	0	0	35	158.98	569
55000	301	34	-60.5	0	92.8	0	0	34	152.04	568
56000	300	35	-59.5	0	88.4	0	0	32	144.20	569
57000	301	31	-59.5	0	84.3	0	0	31	137.41	569
58000	314	24	-59.8	0	80.3	0	0	29	131.09	569

59000	321	20	-60.0	0	76.5	0	0	28	125.01	568
60000	349	13	-58.6	0	72.9	0	0	26	118.30	570
61000	8	11	-57.1	0	69.4	0	0	25	111.93	573
62000	337	10	-58.2	0	66.2	0	0	24	107.26	571
63000	348	9	-57.3	0	63.1	0	0	23	101.83	572
64000	60	13	-56.6	0	60.1	0	0	22	96.77	573
65000	80	18	-56.6	0	57.3	0	0	21	92.25	573
66000	95	21	-56.7	0	54.7	0	0	20	87.98	573
67000	98	10	-57.1	0	52.1	0	0	19	84.03	572
68000	325	4	-56.1	0	49.7	0	0	18	79.72	574
69000	54	11	-55.5	0	47.4	0	0	17	75.82	575
70000	53	9	-55.7	0	45.2	0	0	16	72.37	575
71000	64	9	-56.3	0	43.1	0	0	16	69.18	574
72000	50	14	-55.9	0	41.1	0	0	15	65.85	574
73000	40	16	-55.4	0	39.2	0	0	14	62.65	575
74000	58	19	-55.4	0	37.3	0	0	14	59.74	575
75000	77	24	-55.2	0	35.6	0	0	13	56.93	575
76000	82	29	-55.3	0	34.0	0	0	12	54.33	575
77000	84	31	-54.9	0	32.4	0	0	12	51.71	576
78000	83	23	-55.1	0	30.9	0	0	11	49.36	575
79000	85	13	-55.1	0	29.5	0	0	10	47.08	575
80000	78	18	-55.5	0	28.1	0	0	10	44.98	575
81000	72	29	-55.2	0	26.8	0	0	9	42.83	575
82000	66	26	-54.5	0	25.6	0	0	9	40.72	576
83000	61	20	-53.7	0	24.4	0	0	8	38.71	577
84000	56	15	-52.0	0	23.3	0	0	8	36.65	579
85000	66	15	-50.8	0	22.2	0	0	8	34.80	581
86000	78	35	-50.3	0	21.2	0	0	7	33.15	582
87000	70	34	-49.9	0	20.2	0	0	7	31.60	582
88000	69	25	-49.7	0	19.3	0	0	7	30.15	582
89000	78	24	-49.9	0	18.5	0	0	6	28.80	582
90000	83	26	-50.0	0	17.6	0	0	6	27.52	582
91000	81	24	-49.9	0	16.8	0	0	6	26.27	582
92000	79	18	-49.5	0	16.1	0	0	6	25.04	583
93000	67	12	-49.8	0	15.3	0	0	5	23.94	582
94000	43	7	-50.5	0	14.7	0	0	5	22.92	581

95000	5	5	-51.4	0	14.0	0	0	5	21.97	580
96000	338	4	-51.3	0	13.4	0	0	5	20.96	580
97000	345	2	-51.1	0	12.7	0	0	5	20.00	580
98000	60	4	-50.9	0	12.2	0	0	4	19.07	581
99000	58	9	-50.5	0	11.6	0	0	4	18.18	582
100000	52	16	-50.5	0	11.1	0	0	4	17.36	581
101000	49	23	-51.2	0	10.6	0	0	4	16.62	580
102000	70	21	-49.7	0	10.1	0	0	3	15.76	582
103000	66	14	-48.8	0	9.7	0	0	3	14.99	583
104000	36	8	-48.0	0	9.2	0	0	3	14.27	584
105000	40	12	-47.0	0	8.8	0	0	3	13.57	586
106000	45	14	-46.1	0	8.4	0	0	3	12.92	587
107000	53	12	-45.3	0	8.0	0	0	3	12.31	588
108000	19	11	-45.6	0	7.7	0	0	3	11.78	588
109000	344	14	-46.0	0	7.4	0	0	2	11.28	587
110000	333	15	-46.2	0	7.0	0	0	2	10.78	587
111000	324	16	-46.3	0	6.7	0	0	2	10.30	587
112000	318	14	-45.9	0	6.4	0	0	2	9.83	587
113000	311	12	-45.4	0	6.1	0	0	2	9.37	588
114000	312	10	-45.3	0	5.9	0	0	2	8.96	588
115000	322	9	-45.7	0	5.6	0	0	2	8.58	587
116000	323	7	-45.9	0	5.4	0	0	2	8.21	587
117000	313	6	-45.8	0	5.1	0	0	2	7.84	587
118000	299	6	-45.6	0	4.9	0	0	2	7.49	587
119000	287	8	-45.2	0	4.7	0	0	2	7.15	588
120000	279	10	-44.8	0	4.5	0	0	2	6.82	589
121000	277	11	-44.5	0	4.3	0	0	2	6.51	589
122000	276	12	-44.1	0	4.1	0	0	1	6.21	590
123000	273	15	-43.7	0	3.9	0	0	1	5.93	590
124000	270	20	-43.3	0	3.7	0	0	1	5.66	591
125000	272	24	-42.9	0	3.6	0	0	1	5.40	591
126000	287	26	-42.2	0	3.4	0	0	1	5.15	592
127000	297	28	-41.7	0	3.3	0	0	1	4.92	593
128000	295	26	-41.7	0	3.1	0	0	1	4.71	593
129000	291	25	-41.5	0	3.0	0	0	1	4.50	593
130000	264	31	-39.5	0	2.9	0	0	1	4.27	596

131000	254	36	-38.3	0	2.7	0	0	1	4.06	597
132000	252	39	-37.9	0	2.6	0	0	1	3.88	598
133000	253	42	-38.2	0	2.5	0	0	1	3.72	598
134000	254	46	-38.7	0	2.4	0	0	1	3.57	597
135000	251	56	-38.4	0	2.3	0	0	1	3.41	597
136000	249	67	-38.1	0	2.2	0	0	1	3.26	597
137000	247	73	-38.1	0	2.1	0	0	1	3.12	597
138000	245	79	-38.1	0	2.0	0	0	1	2.98	597

TERMINATION ALTITUDE 138176FT. GEOMETRIC (137265FT. GEOPOTENTIAL)

RADIOSONDE (SMQ) DATA
PGS MONTEREY
FLIGHT NO 16
1756Z 25 JANUARY 1966
STANDARD LEVELS

P	H(MET)	H(FT)	T	TD	RH
1016.3	38	125	10.0	4.4	68
1000.0	172	565	8.5	.7	58
950.0	595	1951	6.0	-0.1	65
900.0	1038	3406	5.7	-7.9	37
850.0	1505	4937	4.4	-14.2	24
800.0	1996	6550	1.9	-13.6	31
750.0	2515	8251	-0.3	-17.9	25
700.0	3062	10045	-4.6	-17.9	35
650.0	3643	11952	-7.1	-21.8	30
600.0	4262	13984	-11.4	-25.9	29
550.0	4924	16156	-15.9	-30.3	28
500.0	5636	18490	-20.0	-33.4	29
450.0	6409	21027	-25.4	-36.1	37
400.0	7253	23797	-29.9	-35.8	57
350.0	8186	26856	-38.7	-48.3	36
300.0	9224	30262	-48.2	.	.
250.0	10394	34103	-58.7	.	.
200.0	11849	38876	-56.1	.	.
175.0	12695	41650	-56.7	.	.
150.0	13668	44842	-58.2	.	.
125.0	14818	48615	-55.2	.	.
100.0	16216	53203	-61.5	.	.
80.0	17601	57745	-61.8	.	.
70.0	18433	60476	-58.3	.	.
60.0	19402	63654	-58.0	.	.
50.0	20554	67433	-57.1	.	.
40.0	21968	72074	-54.7	.	.
30.0	23797	78073	-56.5	.	.

25.0	24959	81887	-53.6	.	.
20.0	26402	86620	-51.0	.	.
15.0	28274	92761	-51.4	.	.
10.0	30909	101408	-49.6	.	.
7.0	33269	109152	-46.5	.	.
5.0	35522	116544	-45.5	.	.
4.0	36992	121364	-45.2	.	.
3.0	38916	127677	-44.3	.	.
2.0	41674	136727	-41.5	.	.

SIGNIFICANT LEVELS

P	T	TD	H(MET)	H(FT)	N
1016.3	10.0	4.4	38	125	317
1000.0	8.5	.7	172	565	306
949.0	6.0	-0.1	603	1979	293
943.0	6.7	-0.3	655	2149	290
894.0	5.6	-9.4	1093	3584	263
842.0	4.3	-15.1	1581	5187	245
834.0	4.6	-15.3	1659	5442	242
816.0	3.0	-12.9	1836	6023	240
770.0	.6	-18.2	2303	7556	226
697.0	-4.8	-18.0	3095	10155	209
606.0	-11.0	-25.3	4185	13731	184
524.0	-18.5	-32.3	5287	17345	162
513.0	-19.8	-33.4	5445	17863	159
506.5	-19.4	-33.0	5539	18173	157
424.0	-28.8	-35.9	6837	22432	136
350.0	-38.7	-48.3	8186	26856	116
323.0	-43.5	.	8731	28647	109
244.0	-59.3	.	10546	34600	89
241.0	-56.9	.	10624	34857	86
232.0	-55.4	.	10866	35650	83
223.5	-24.2	.	11121	36487	70

215.0	-54.5	.	11387	37358	76
139.5	-60.0	.	14123	46334	51
134.5	-58.7	.	14351	47083	49
130.0	-54.5	.	14567	47791	46
54.5	-57.6	.	20009	65645	20
42.5	-57.4	.	21582	70805	15
40.2	-54.5	.	21936	71967	14
3.0	-44.3	.	38916	127677	1
2.5	-39.2	.	40151	131731	1
2.0	-41.5	.	41674	136727	1
1.8	-38.8	.	42393	139086	1

ALTITUDE INTERVAL 1000FT.

H	DDD	FF	T	TD	P	RH	W	N	D	CS
125	.	.	10.0	4.4	1016.3	68	5.2	317	1246.52	656
1000	.	.	7.7	.5	984.0	61	4.0	302	1217.92	653
2000	.	.	6.1	-0.1	948.3	65	4.0	293	1180.23	651
3000	.	.	5.9	-4.6	913.7	47	3.0	275	1138.50	651
4000	.	.	5.2	-10.9	880.3	30	1.9	258	1100.61	649
5000	.	.	4.4	-14.5	847.9	24	1.5	247	1063.33	649
6000	.	.	3.1	-13.0	816.8	30	1.7	240	1029.06	647
7000	.	.	1.2	-15.1	786.5	29	1.5	232	997.86	646
8000	.	.	.0	-18.0	757.2	24	1.2	223	964.87	644
9000	.	.	-2.0	-17.3	728.8	30	1.4	216	935.80	641
10000	.	.	-4.4	-17.8	701.3	35	1.3	210	908.52	638
11000	.	.	-5.3	-20.1	674.7	30	1.1	202	876.85	638
12000	.	.	-7.2	-21.8	648.9	30	1.0	194	849.51	636
13000	.	.	-9.5	-23.6	623.9	31	.9	188	823.95	632
14000	.	.	-11.4	-25.9	599.8	29	.8	182	798.01	630
15000	.	.	-13.3	-28.0	576.3	28	.7	176	772.34	628
16000	.	.	-15.5	-30.0	553.7	28	.5	170	748.29	625
17000	.	.	-17.7	-31.8	531.7	29	.5	164	724.95	623
18000	.	.	-19.6	-33.2	510.4	29	.4	158	701.25	620

19000	.	.	-20.8	-33.9	489.9	30	.4	153	676.18	619
20000	.	.	-23.3	-35.7	470.1	32	.4	148	655.37	616
21000	.	.	-25.3	-36.0	450.8	37	.4	143	633.58	613
22000	.	.	-27.8	-36.3	432.3	45	.4	138	613.63	610
23000	.	.	-29.3	-35.8	414.3	54	.4	133	591.75	608
24000	.	.	-30.7	-36.9	397.0	55	.4	129	570.29	607
25000	.	.	-33.9	-41.9	380.2	45	.2	124	553.54	602
26000	.	.	-36.5	-45.8	364.0	38	.2	120	535.75	599
27000	.	.	-39.0	-49.1	348.3	34	.1	116	518.17	597
28000	.	.	-41.7	0	333.1	0	0	112	501.38	592
29000	.	.	-44.4	0	318.4	0	0	108	484.95	589
30000	.	.	-47.3	0	304.2	0	0	104	469.23	585
31000	.	.	-50.4	0	290.5	0	0	101	454.25	582
32000	.	.	-53.5	0	277.1	0	0	98	439.57	578
33000	.	.	-56.2	0	264.3	0	0	95	424.31	574
34000	.	.	-58.5	0	251.9	0	0	91	408.84	571
35000	.	.	-56.7	0	240.0	0	0	86	386.37	573
36000	.	.	-44.7	0	229.0	0	0	79	349.93	589
37000	.	.	-39.8	0	219.1	0	0	73	327.72	595
38000	.	.	-55.4	0	209.2	0	0	75	334.64	575
39000	.	.	-56.1	0	199.5	0	0	71	320.21	574
40000	.	.	-56.9	0	190.1	0	0	68	306.30	573
41000	.	.	-56.9	0	181.2	0	0	65	291.94	573
42000	.	.	-56.7	0	172.8	0	0	62	278.11	573
43000	.	.	-57.5	0	164.7	0	0	60	266.01	572
44000	.	.	-58.5	0	156.9	0	0	57	254.65	571
45000	.	.	-58.3	0	149.5	0	0	54	242.47	571
46000	.	.	-59.4	0	142.5	0	0	52	232.21	570
47000	.	.	-59.0	0	135.7	0	0	50	220.85	570
48000	.	.	-54.6	0	129.4	0	0	46	206.23	576
49000	.	.	-55.7	0	123.4	0	0	44	197.64	575
50000	.	.	-57.7	0	117.6	0	0	42	190.17	572
51000	.	.	-60.0	0	112.1	0	0	41	183.14	569
52000	.	.	-60.6	0	106.8	0	0	39	174.96	568

53000	.	.	-61.2	0	101.7	0	0	37	167.12	567
54000	.	.	-61.6	0	96.8	0	0	36	159.44	566
55000	.	.	-61.1	0	92.2	0	0	34	151.47	567
56000	.	.	-61.3	0	87.8	0	0	32	144.40	567
57000	.	.	-61.6	0	83.6	0	0	31	137.70	566
58000	.	.	-61.9	0	79.6	0	0	29	131.28	566
59000	.	.	-61.1	0	75.8	0	0	28	124.53	567
60000	.	.	-58.6	0	72.2	0	0	26	117.29	570
61000	.	.	-58.7	0	68.8	0	0	25	111.80	571
62000	.	.	-59.1	0	65.6	0	0	24	106.75	570
63000	.	.	-58.3	0	62.5	0	0	23	101.32	571
64000	.	.	-57.9	0	59.6	0	0	22	96.40	571
65000	.	.	-57.3	0	56.8	0	0	20	91.64	572
66000	.	.	-57.6	0	54.1	0	0	20	87.48	572
67000	.	.	-57.6	0	51.6	0	0	19	83.37	572
68000	.	.	-56.6	0	49.2	0	0	18	79.10	573
69000	.	.	-57.0	0	46.9	0	0	17	75.55	573
70000	.	.	-57.2	0	44.7	0	0	16	72.08	572
71000	.	.	-57.4	0	42.6	0	0	15	68.77	572
72000	.	.	-55.0	0	40.6	0	0	14	64.87	575
73000	.	.	-55.8	0	38.7	0	0	14	62.08	574
74000	.	.	-56.5	0	36.9	0	0	13	59.39	573
75000	.	.	-56.4	0	35.2	0	0	13	56.60	574
76000	.	.	-56.3	0	33.6	0	0	12	53.94	574
77000	.	.	-57.3	0	32.0	0	0	12	51.66	572
78000	.	.	-56.3	0	30.5	0	0	11	49.03	574
79000	.	.	-56.7	0	29.1	0	0	10	46.83	573
80000	.	.	-55.8	0	27.7	0	0	10	44.47	575
81000	.	.	-55.0	0	26.5	0	0	9	42.24	575
82000	.	.	-53.7	0	25.2	0	0	9	40.07	577
83000	.	.	-53.0	0	24.1	0	0	8	38.09	578
84000	.	.	-52.3	0	23.0	0	0	8	36.24	579
85000	.	.	-51.6	0	21.9	0	0	8	34.48	580
86000	.	.	-51.2	0	20.9	0	0	7	32.85	580
87000	.	.	-51.0	0	20.0	0	0	7	31.33	581
88000	.	.	-50.6	0	19.1	0	0	7	29.86	581
89000	.	.	-51.2	0	18.2	0	0	6	28.59	580
90000	.	.	-51.2	0	17.4	0	0	6	27.28	581

91000	.	.	-50.9	0	16.6	0	0	6	26.02	581
92000	.	.	-50.9	0	15.8	0	0	6	24.83	581
93000	.	.	-51.3	0	15.1	0	0	5	23.75	580
94000	.	.	-51.8	0	14.4	0	0	5	22.72	579
95000	.	.	-51.9	0	13.8	0	0	5	21.70	579
96000	.	.	-51.2	0	13.2	0	0	5	20.64	581
97000	.	.	-51.3	0	12.6	0	0	4	19.71	580
98000	.	.	-51.6	0	12.0	0	0	4	18.84	580
99000	.	.	-51.7	0	11.4	0	0	4	18.00	580
100000	.	.	-50.9	0	10.9	0	0	4	17.11	581
101000	.	.	-50.2	0	10.4	0	0	4	16.29	581
102000	.	.	-49.5	0	10.0	0	0	3	15.51	582
103000	.	.	-49.0	0	9.5	0	0	3	14.77	583
104000	.	.	-48.5	0	9.1	0	0	3	14.08	584
105000	.	.	-47.9	0	8.7	0	0	3	13.41	585
106000	.	.	-47.4	0	8.3	0	0	3	12.79	585
107000	.	.	-47.0	0	7.9	0	0	3	12.19	586
108000	.	.	-46.7	0	7.6	0	0	3	11.64	586
109000	.	.	-46.6	0	7.2	0	0	2	11.11	586
110000	.	.	-46.5	0	6.9	0	0	2	10.62	586
111000	.	.	-46.6	0	6.6	0	0	2	10.15	586
112000	.	.	-46.7	0	6.3	0	0	2	9.70	586
113000	.	.	-46.2	0	6.0	0	0	2	9.25	587
114000	.	.	-45.7	0	5.8	0	0	2	8.83	587
115000	.	.	-45.2	0	5.5	0	0	2	8.42	588
116000	.	.	-45.3	0	5.3	0	0	2	8.05	588
117000	.	.	-45.4	0	5.0	0	0	2	7.70	588
118000	.	.	-45.5	0	4.8	0	0	2	7.36	588
119000	.	.	-45.5	0	4.6	0	0	2	7.04	588
120000	.	.	-45.4	0	4.4	0	0	2	6.72	588
121000	.	.	-45.3	0	4.2	0	0	1	6.42	588
122000	.	.	-45.2	0	4.0	0	0	1	6.13	588
123000	.	.	-45.1	0	3.8	0	0	1	5.86	588
124000	.	.	-45.0	0	3.7	0	0	1	5.60	589

125000	•	•	-44.9	0	3.5	0	0	1	5.35	589
126000	•	•	-44.7	0	3.4	0	0	1	5.11	589
127000	•	•	-44.6	0	3.2	0	0	1	4.88	589
128000	•	•	-44.4	0	3.1	0	0	1	4.67	589
129000	•	•	-43.6	0	2.9	0	0	1	4.45	590
130000	•	•	-42.4	0	2.8	0	0	1	4.23	592
131000	•	•	-41.1	0	2.7	0	0	1	4.02	593
132000	•	•	-39.9	0	2.6	0	0	1	3.83	595
133000	•	•	-39.3	0	2.5	0	0	1	3.65	596
134000	•	•	-39.6	0	2.3	0	0	1	3.50	596
135000	•	•	-40.0	0	2.2	0	0	1	3.36	595
136000	•	•	-40.4	0	2.1	0	0	1	3.22	595
137000	•	•	-41.1	0	2.1	0	0	1	3.09	594
138000	•	•	-41.1	0	2.0	0	0	1	2.96	593
139000	•	•	-40.0	0	1.9	0	0	1	2.82	595
140000	•	•	-38.8	0	1.8	0	0	1	2.68	596

TERMINATION ALTITUDE 140021 FT. GEOMETRIC (139086 FT. GEOPOTENTIAL)

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13. ABSTRACT

Radiosonde information is extensively used in the analysis and forecast of meteorological phenomena and the accuracy of both analyses and forecasts is dependent primarily upon the accuracy of the meteorological parameters determined from radiosonde flights. To evaluate the accuracy obtainable, 50 radiosonde flights were launched from the U. S. Naval Postgraduate School, Monterey, California. Thirty-five flights carried aloft the AN/AMT-4B model transmitter alongside the prototype AN/AMT-11DX transmitter and 15 flights carried the AN/AMT-11C model along with the AN/AMT-4B. All data obtained were reduced by the Geophysics Division, Pacific Missile Range, Point Mugu, California, on a CDC-3100 computer and graphically by the experimenter on the WBAN-31 series adiabatic charts. Values of temperature, relative humidity, and pressure as determined by each instrument were compared at each 3-minute interval of each flight and values of temperature, pressure-altitude, relative humidity and dewpoint were compared at standard pressure levels. The results obtained afforded a realistic evaluation of the various sensing elements under field conditions and indicate an urgent requirement for the development of a more accurate water vapor sensing device and replacement of the radiosonde baroswitching circuit by a hypsometer for precise determination of pressure values.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radiosonde Accuracy						
Ceramic-Resistor Temperature Element						
Carbon Humidity Element						
Lithium-Chloride Humidity Element						
Baroswitch						
Hypsometer						
Computer Reduction of Radiosonde Data						

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